PROGRAMME

56TH IWK

International Scientific Colloquium
Ilmenau University of Technology

12 – 16 September 2011

Innovation in Mechanical Engineering – Shaping the Future

Faculty of Mechanical Engineering

www.tu-ilmenau.de

ILMENAU UNIVERSITY OF TECHNOLOGY

ISBN 978-3-86360-001-3
URN urn:nbn:de:gbv:ilm1-2011iwk-prg:0

Impressum

Herausgeber:
Der Rektor der Technischen Universität Ilmenau
Univ.-Prof. Dr. rer. nat. habil. Dr. h. c. Prof. h. c. mult.
Peter Scharff

Redaktion:
Referat Marketing
Andrea Schneider, Katrin Maletschek
conferences@tu-ilmenau.de

Redaktionsschluss:
18. August 2011

Verlag:
Universitätsbibliothek / Universitätsverlag Ilmenau
Postfach 10 05 65
98684 Ilmenau
www.tu-ilmenau.de/universitaetsverlag

Druck:
Verlagshaus Monsenstein und Vannerdat OHG
Am Hawerkamp 31
48155 Münster
www.mv-verlag.de

Gestaltung:
Torsten Weilepp

Preface

Dear Conference Participants

We are delighted to welcome you to Ilmenau University of Technology for the 56th International Scientific Colloquium (Internationales Wissenschaftliches Kolloquium, IWK). The IWK looks back on fifty-six years of tradition in exchanging scientific ideas and bridging disciplines.
In 2011, the International Scientific Colloquium is again organised by the Faculty of Mechanical Engineering. The title of this year's conference:

"Innovation in Mechanical Engineering – Shaping the Future",

is intended to reflect both the width and the depth of modern Mechanical Engineering. In three main headings many research areas are addressed, all involving innovations in Mechanical Engineering:

- Precision Engineering and Precision Measurement Technology
- Mechatronics and Ambient Assisted Living
- Systems Technology

The Colloquium, complemented by workshops, is characterised by the topics listed above, but not narrowly limited to them.
The main subjects of this year's IWK are those facets of Mechanical Engineering in which our own Faculty strives to excel, as a centre of both research and teaching. They are also part of the dedicated research strategy which Ilmenau University of Technology as a whole has defined as a strategic guideline.

As always in the long series of IWK conferences, we invite and encourage contributions both from academia and industry. No matter whether you are an experienced professional or a novice in mechanical engineering – we are convinced that the 56th International Scientific Colloquium in Ilmenau will be of benefit to you.

The discussions during the IWK will doubtless be both wide and deep, exciting and exhaustive, providing the material, we are sure, for further publications in the various respective subject-related journals.

We are delighted with the response to the call for papers. After careful international reviewing, 166 contributions remain for presentation, representing 21 countries. The range of subjects certainly reflects the interdisciplinary nature of the conference topics and will bring together industrialists and scientists from a variety of disciplines.

Besides a fruitful and interesting professional exchange of views, we wish you an enjoyable stay in the town of Ilmenau and its surroundings. The town has close connections to Johann Wolfgang von Goethe who already 200 years ago appreciated its beauty and came back many times, both on business and for pleasure. Perhaps the 56th IWK will inspire you to follow in his footsteps!

Univ.-Prof. Dr. rer. nat. habil.
Dr. h. c. Prof. h. c. mult. Peter Scharff
(Professor Peter Scharff)
Rector of the Ilmenau University
of Technology

Univ.-Prof. Dr.-Ing. habil.
Prof. h. c. Peter Kurtz
(Professor Peter Kurtz)
Dean of the Faculty of
Mechanical Engineering

56th IWK, 12 – 16 September 2011

Table of Contents

Last update: 18.08.2011

CONFERENCE PROGRAMME AT A GLANCE (Subject to alteration)

56th International Scientific Colloquium 12 – 16 September 2011

Room / Date	Audimax	010	012	129	204	211/212	HU-HS	EAZ	Arrhenius Building	Foyer	210	117
Sunday, 11.09.11 5:00 p.m. – 9.00 p.m.										Registration in the Conference Office		
Monday, 12.09.11 8:00 a.m. – 4:00 p.m.										Registration and Company Presentations	Internet-Cafe	Wardrobe
9:00 p.m. – 12:00 p.m.						3.1.1				Registration and Company Presentations		
1:30 p.m – 3:30 p.m	Opening of the 56th IWK (Plenary Session)									Registration and Company Presentations		
3:30 p.m. – 7:00 p.m.	Foyer Humboldt Building: Welcome Reception for all speakers, participants, companies and guests											
Tuesday, 13.09.11 9:00 a.m. - 12:00 noon			1st OCTI		1.5	3.1.2	1.2			Registration and Company Presentations		
1:30 p.m – 4:30 p.m.		1.3	1st OCTI		1.5	3.1.3	1.2			Registration and Company Presentations		
12:00 noon – 1:30 p.m.	Poster Session: 1.2, 1.3, 1.5, 3.1.1, 3.1.3, 3.2, LGO											
8:00 p.m.	Ilmenau's Festival Hall: Academic Gala Concert											
Wednesday, 14.09.11 9:00 a.m. – 12:00 noon		1.3		2.2		1.2	3.2		LGO	Registration and Company Presentations		
1:00 p.m. – 2:00 p.m.	Start from the Humboldt Building: Scientific guided tours (any one time)											
2:15 p.m. – 10.30 p.m.	Start from the Mensa (Refectory): Excursion to Wartburg Castle (World Heritage) Eisenach, afterwards Banquet in the Hotel "Tanne", Ilmenau											
Thursday, 15.09.11 9:00 a.m. – 12:00 noon				2.2			1.1	WS VE		Registration and Company Presentations		
1:30 p.m. – 4:30 p.m.				2.1			1.1	WS VE		Registration and Company Presentations		
12:00 noon – 1:30 p.m.	Poster Session: 1.1, 2.1, 2.2											
Friday, 16.09.11 9:00 a.m. – 12:00 noon				1.WS OFT								
Friday, 16.09.11 1:30 p.m. – 4:30 p.m.				1.WS OFT								
Legend	Sessions of the 56th IWK	Accompanying Programme of the 56th IWK							Further Events/Workshops			

- 1st OCTI - 1st International Symposium OCTI 2011
- 1. WS OFT – 1. Workshop Oberflächentechnik
- LGO – Workshop "Lebendige Glasoberflächen"
- WS VE - Workshop "Virtual Engineering throughout the Product Lifecycle

Conference Office

Registration

Organisation

Ilmenau University of Technology
Conference Management / Conference Office
Mrs Andrea Schneider

Postal Address:
PF 10 05 65, 98684 Ilmenau, Germany
Tel.: +49 3677 69-2520
Fax: +49 3677 69-1743
e-Mail: conferences@tu-ilmenau.de

Conference Office

Humboldt Building
TU Ilmenau, Gustav-Kirchhoff-Platz 1
Phone: +49 3677 69-2790, 69-2791
Mobile: +49 171 764 48 23
Fax: +49 3677 69-1743

Opening hours/ Registration

Sunday, 11.09.11	5:00 p.m. – 9:00 p.m.
Monday, 12.09.11	8:00 a.m. – 4:00 p.m.
Tuesday, 13.09.11	8:00 a.m. – 8:00 p.m.
Wednesday, 14.09.11	8:00 a.m. – 12:30 p.m.
Thursday, 15.09.11	8:00 a.m. – 8:00 p.m.
Friday, 16.09.11	8:00 a.m. – 5:00 p.m.

Conference Programme

Opening Ceremony and Plenary

Monday, 12.09.11, 1:30 p.m./Audimax	Musical opening by the Members of the Fraunhofer Institute for Digital Media Technology IDMT in Ilmenau, Gabriel Gatzsche and Markus Mehnert.
Moderation	Professor Mathias Weiß, Head of Organisation
1:35 p.m.	**The participants will be welcomed by** - Professor Peter Scharff Rector, Ilmenau University of Technology - Professor Peter Kurtz Dean of the Faculty of Mechanical Engineering - Matthias Machnig Minister of the Thuringian Ministry for Industry, Employment and Technology Musical interlude
2:00 p.m.	**Plenary Lecture** Professor Klaus Wucherer erstwhile Board Member, Siemens AG, Chairman of the Board, Infineon AG. Member of Senate, University Erlangen-Nuremberg **"Production – the Key to Sustainable Competitiveness"**
3:00 p.m.	**Celebratory Lecture** Professor Michael Schenk, Director, IFF Fraunhofer Institute, Magdeburg, Member of National Executive, Chair of Regional Committee, VDI **„The 150th Anniversary of the Thüringen VDI"**
3:30 p.m.	**End of the Opening Ceremony and Plenary**

General Information

Catering

Coffee break refreshments

At the colloquium, refreshments will be offered during the coffee breaks in the foyer of the conference building.

Meals and Refreshments

All participants may take advantage of the catering service in the Mensa (refectory) of the university. You can get there within a few walking minutes from the conference building.

The cafeteria "MINI" at the Humboldt Building also provides meals and beverages on a limited scale.

Topic 1:

Precision Engineering and Precision Measurement Technology

Session 1.1 Nanopositioning and Nanomeasuring Technology

Time: Thursday, 15.09.2011
Location: Humboldt Building, Humboldt Lecture Hall
Chairmen: E. Manske (D-Ilmenau), R. Leach (UK-Teddington)

9:00 a.m.	R. Leach (UK-Teddington)

Advances in engineering nanometrology at the National Physical Laboratory

The National Physical Laboratory, UK has been active in the field of engineering nanometrology for a number of years. A summary of progress over the last five years is presented in this paper and the following research projects discussed in detail: 1. Development of an infrastructure for the calibration of instruments for measuring areal surface topography, along with the development of areal software measurement standards. This work comprises the use of the optical transfer function and a technique for the simultaneous measurement of topography and the phase change on reflection, allowing composite materials to be measured. 2. Development of a vibrating micro-CMM probe with isotropic probing reaction and the ability to operate in a non-contact mode. 3. A review of x-ray computed tomography and its use in dimensional metrology. 4. The further development of a metrology infrastructure for atomic force microscopy and the development of an instrument for the measurement of the effect of the probe-surface interaction. 5. Traceable measurement of displacement using optical and x-ray interferometry to picometre accuracy. 6. Development of an infrastructure for low force metrology, including the development of appropriate transfer artefacts.

9:40 a.m.	E. Manske, G. Jäger, T. Hausotte, R. Füßl (D-Ilmenau)

Prospects and Challenges of Nanopositioning and Nanomeasuring Technology

The paper deals with the requirements for highest measurement performance at the limits of physics and technologies which result from the progress and the goals of modern high-tech fabrication technologies. The nanopositioning and nanomeasuring technology enables today high precision scale-bridging measurement and positioning of objects from subnanometre up to some centimeter. The basis, progress and the prospects of the Nanopositioning and Nanomeasuring Machine, developed at Institute of Process Measurement and Sensor Technology of the Ilmenau University of Technology and manufactured by the SIOS Messtechnik GmbH Ilmenau, are demonstrated.

10:00 a.m.	G. Dai, S. Bütefisch, F. Pohlenz, H.-U. Danzebrink, J. Fluegge (D-Braunschweig)

True 3D measurements of micro and nano structures

True 3D measurements of micro and nano structures remain challenging issues today. In this paper, a newly developed 3D-AFM and an NMM based ultra precision micro/nano CMM are introduced for true 3D measurements of micro and nano structures. In the design of the 3D-AFM, the AFM probe is oscillated by two piezo actuators driven at vertical and/or torsional resonant frequencies of the cantilevers. This enables the AFM tip to probe the surface with a vertical and/or a lateral oscillation, offering high 3D probing sensitivity. In addition, a

so called "vector approach probing" (VAP) method is applied for enhancing the measurement flexibility and minimising the tip wear. Some preliminary experimental results of the 3D-AFM are demonstrated, showing very promising performance. The measurement of an IVPS 100 sample employing a flared AFM tip is performed, showing a repeatability of its 3D profiles of better than 1 nm (p-v). A single crystal critical dimension reference material (SCCDRM) having features with almost vertical sidewalls is measured using a flared AFM tip. Results show that the feature has averaged left and right sidewall angles of 86.1° and 86.8°, respectively. However, the feature width non-uniformity may reach 10 nm within the measurement range of 1 µm. The standard deviation of the averaged middle CD values of 22 repeated measurements reaches 0.3 nm. In addition, an investigation of long term measurement stability is performed on a PTB photomask. The results change with a rate of about 0.00033 nm per line, which confirms the high measurement stability and the very low tip wear. In the developed micro/nano CMM, two kind of tactile probes are applied: a piezoresistive probe and an ACP ball probe. Its probing repeatability reaches 1.3 nm, 4.4 nm and 4.4 nm along the x, y and z axes, respectively. Calibration of micro/nano NMMs remains a critical issue. A novel 3D test artefact fabricated using the wet etching technique is introduced, which is capable of characterising the 3D geometric properties of micro/nano CMMs with only one measurement.

10:20 - 10:40 Coffee break

10:40 a.m. | A. Yacoot (UK-Middlesex), U. Kuetgens (D-Braunschweig)

Digital control of x-ray interferometers for measurement of sub nanometre errors in optical interferometers

Within the European Metrology Research Programme project NANOTRACE, the non-linearity of the next generation of optical interferometers developed by European metrology Institutes has been measured using x-ray interferometry. The x-ray interferometer (XRI) can be regarded as a ruler or translation stage whose graduations (fringes) or displacement steps, in this case 0.192 nm, are traceable to the lattice parameter of silicon. Integral mirrors on the side of the XRI provide a reference for the optical interferometers under test.

A servo control system based on a field programmable gate array (FPGA) platform has been developed for fine control of the XRI. It 'locks' the XRI onto the zero crossing point of an x-ray fringe holding the XRI's position constant to within a few picometres. Increasing the PZT voltage faster than the response time of the servo control allows movement of the XRI in quantized steps of individual x-ray fringes. One x-ray fringe corresponds to a voltage step of ~ 0.121 mV from the digital to analogue converter (DAC), which, with the gain of 100 from the high voltage power supply, corresponds to 12.1 mV on the pzt. The resolution of the FPGA DAC output is ± 10/215 ≡ ± 0.305 mV - clearly insufficient. The required servo rate is 1-2 kHz, however, the FPGA DAC's output rate is 1 MHz. A HyperBit routine increases the DAC output resolution by dithering the least significant bit on the DAC output in the temporal domain giving an output resolution of 0.01 bit equivalent to. 3.05 µV (5 pm). This is equivalent to a 21 bit DAC output. By stepping the XRI through sufficient x-ray fringes to traverse a distance equivalent to an optical fringe, it is possible to measure the non-linearity in an optical fringe.

Optical interferometer non-linearity of the order of 10 pm has been measured. By introducing a phase shift of $\pi/2$ radians between the two beams exiting the XRI it has been possible to count x-ray fringes in quadrature. This enables a bi-directional measurement of the mo-

tion of the XRI based on fringe counting to be realised analogous to that in an optical interferometer, but with a period of 0.192 nm instead of several hundred nanometres.

11:00 a.m.	T. Hausotte (D-Erlangen), B. Percle, U. Gerhard, D. Dontsov, E. Manske, G. Jäger (D-Ilmenau)

Homodyne Interference Signal Demodulation for Nanopositioning and Nanomeasuring Machines

The Nanopositioning and Nanomeasuring Machine NMM-1 developed at the Ilmenau University of Technology was designed for measurements within a measuring volume of 25mm by 25mm by 5mm. The interferometric length measuring and drive systems make it possible to move the stage and corner mirror with a resolution of 0.1 nm in all three axes. The object being measured is placed on the corner mirror and can be measured with different probe systems. The high precision of the machine can be attributed to several factors, including the accuracy of the interferometricmeasuring systems, the three-dimensional realization of the Abbe comparator principle, the precise reference coordinate system defined by the corner mirror and the additional compensation of angular deviations. Starting with an improved equation for length calculation, this article describes a part of the measurement uncertainty analysis for a displacement measurement using two positions of the measuring mirror. In particular this article discusses the influence of offset, amplitude and phase deviations in the interference signals.

11:20 a.m.	P. Köchert, J. Flügge, C. Weichert, R. Köning (D-Braunschweig), E. Manske (D-Ilmenau)

Displacement interferometry of various commercial heterodyne HeNe-laser-systems with stability in the sub-nanometer regime

Heterodyne laser interferometer systems have become instruments of choice for position measurements in precision machining and at the national metrology institutes. In order to be able to resolve displacements of a picometer with heterodyne interferometers an advanced phase meter was developed at PTB. Key to this level of interpolation is the use of a state-of-the-art ADC board enabling an implementation of a phase evaluation method by using embedded field programmable gate arrays (FPGA). Experimental results obtained with commercially available heterodyne laser interferometer components prove that the proposed phase evaluation procedure is capable to interpolate an optical fringe down into the picometer regime. The phase evaluation was moreover extended to track simultaneously two heterodyne beat frequencies with only two photo detectors and ADCs.
Potential limitations of the long-term stability of heterodyne interferometers are discussed.

11:40 a.m.	B. Percle, J. Klöckner, E. Manske, W. Fengler (D-Ilmenau)

Signal and Data Processing in High-Precision Measuring Machines – a Case Study of the NPMM-200

The Nanopositioning and Nanomeasuring Machine NPMM-200 represents the latest generation of measurement and positioning devices with sub-nanometer precision, a continuing topic of research at the Ilmenau University of Technology. This new device possesses a positioning range of 200 mm x 200 mm x 25 mm with an ultimate measurement resolution of 0.08 nm and an expected overall uncertainty well below 30 nm. Naturally, this goal puts high demands on the measuring and positioning subsystems, including signal processing and communication. The achievable clock rate is of significant importance for the properties of speed and accuracy within the overall system in order to realize a suitable measurement procedure acceptable to the users. The primary problem for the computer-supported signal processing in the machine (especially with respect to filters, correction calculations and control algorithms) is the requirement that calculations must occur at a monotone rate without significant jitter and without violating deadlines. This contribution discusses the realization of a system for the signal and data processing of position-dependent measurement data based on FPGA technology. The signal and data processing sub-system for the device's position-dependent measurement data can handle 18 analog signals (position and angle information) derived from the main mechanical, electrical and optical systems. Several correction steps are necessary to take into account the various influencing factors: systematic non-linearities resulting from alignment and similar errors in the interferometers, environment components, mirrors with non-orthogonal angles and less than perfect flatness and Abbe errors between the probe system and the specimen. The article discusses several challenges identified during the realization of the signal and data processing system, including the high clock rate, prevention of latency and the execution of the complex algorithms during pre- and post-processing. These challenges were met using standardized PXI and FPGA hardware components, which allow a high degree of parallel computation. However, the large amount of parallel processing requires that data fusion be performed over a specially-designed communications interface.

12:00 noon – 1:30 p.m. Lunch

Session 1.1 Nanopositioning and Nanomeasuring Technology

Time: Thursday, 15.09.2011

Location: Humboldt Building, Humboldt Lecture Hall

Chairmen: A. Yacoot (UK-Middlesex), T. Hausotte (D-Erlangen)

1:30 p.m.	St. Hesse, Chr. Schäffel, H.-U. Mohr, H.-J. Büchner (D-Ilmenau)

Interferometric controlled planar positioning system with zerodur slider

Future high technology applications for example in the semiconductor or the optical industry require positioning systems providing repeatability and uncertainty in the range of nanometers together with x-, y- travel ranges of several hundreds of millimeters. We contribute in this research by investigating the applicability of integrated planar direct drives for the realization of nanopositioning- and nanomeasuring machines (NPM/NMM). The paper introduces the concept of planar integrated direct drives and explains the engineering design of the realized system for a 100 mm circular travel range in x and y. It presents the drive system parameters and the arrangement and interaction of the main components. The results of the initial operation are presented with a special focus on the question how the closed loop system can be taken into operation with a free floating slider. As an important result of the performance evaluation and the measurement of the coincidental z-vibration a servo error of less than ex=0.33 nm and ey=0.45 nm was achieved in standstill operation while the z-vibration with a standard deviation of sz=0.77 nm is also only in the low nanometer range. Regarding the drive system these results represent the limit of what can be reached with this set-up as the measured error motions are in the range of the noise of the fixed environment set-up. By measuring the characteristics of the aerostatic slider support at the fully assembled system the present air bearing stiffness is determinated and based on a FEM-simulation of the slider eigenfrequencies the influence on the force transfer behavior is expected to be only marginal.

1:50 p.m.	A. Schuler, A. Weckenmann, R. J. B. Ngassam (D-Erlangen)

Enhanced measurement of steep surfaces by sensor tilting

In the field of tactile surface probing the contact point between the probing tip and the surface varies depending on the local surface slope. In the case of 2.5D systems like profilometers or AFMs with conical or pyramidal probing tips the measurement of high slopes leads to large deviations as the probing point no longer lies on the tip's apex. Therefore a probing principle is investigated that applies a surface slope dependent sensor tip rotation. By maintaining an orthogonal orientation to the surface during the measurement a nonambiguous contact situation is realized and the measurement deviation resulting from shape superposition is reduced. To realize the tilting, strategies are necessary to determine the optimal tip rotation angle for each surface point. Depending on previous knowledge of the surface and requirements on measurement time and deviation several approaches are thinkable. In the case of knowledge based strategies an ideal model of the surface already exists, e.g. as a CAD file, and the ideal angle can be calculated. In the case of analyzing strategies the surface is acquired without sensor tilting in a first pass to have a data basis for a second pass with tilting. Another class uses prediction algorithms to perform a single-pass scan with sensor rotation based on the already acquired surface points. Additionally a combination of multiple strategies is also possible. To determine the most suited strategies and the best algorithms for each strategy a simulation and analysis environment was devel-

oped. Based on a collision model between the tip and a surface it gives the ability to simulate measurements on user-defined surfaces like a hemisphere or a micro-contour artifact, respecting the physical restrictions of possible positioning mechanics. Evaluation criteria for the comparison are e.g. the resulting deviation, the total measurement time or the necessary tilt velocity. The results are used to determine the best strategy and associated algorithms for a specific measurement task and a specific positioning system. The researched strategies will be implemented in a test stand consisting of a nanopositioning machine type SIOS NMM-1 and a rotation device with a guidance deviation compensation field to realize dynamic sensor tilting in a prototype.

2:10 p.m. | J. Niehues, P. Lehmann (D-Kassel)

Low coherent Linnik interferometer optimized for use in Nano Measuring Machines

The precise and fast acquisition of three-dimensional geometrical data of microcomponents such as micro electro-mechanical systems (MEMS) and micro optical electromechanical systems (MOEMS) is crucial for many advanced fabrication processes. Due to the measurement principle, in scanning white light interferometry (SWLI) the axial resolution is independent of the field of view. In practice it is in the nanometer range which is sufficient for most applications. For the mentioned objects the lateral resolution of the measurement system is far more critical. The requirements for a 3D measuring optical sensor in a Nano Measuring Machine are very high. The resolution in every dimension has to be as high as possible. Another demand is to avoid any collision with the measuring object or the machine itself. In contrast to the most used Mirau interferometer a Linnik setup does not need any component in front of the objective lens. This benefit permits both, a long working distance and a high lateral resolution. In the EC-funded project "NanoCMM" we developed a compact sensor based on a Linnik interferometer. The working distance of more than 5 mm allows measurements without entering the measurement volume of the machine. By wavelength reduction an enhancement of the lateral resolution down to 0.3 μm was achieved. LEDs emitting in the blue and near UV range were used for illumination. A silicon pitch standard with 9 rectangular gratings ranging from 0.3 μm to 6 μm pitch length was used to test the sensor and compare the results with those of a conventional Mirau system. The accuracy depends strongly on whether only the contrast maximum is evaluated, or the phase of the interference signal is taken into account. The experimental results show, that the lateral resolution in SWLI is not defined satisfactorily. The transfer characteristic is different from 2D microscopy. The diffraction limited optical resolution according to the Rayleigh criterion does not increase by a factor of two to three as the guideline VDI/VDE 2655-1.1 states. The instrument transfer function (ITF) introduced by de Groot et. al. [1] does also not correspond to the results we obtained evaluating the signal phase. The Linnik interferometer measures the full modulation depth and the rectangular shape of the pitch standard even if the pitch length is close to the Rayleigh resolution limit. [1] P. de Groot, X. C. de Lega, "Interpreting interferometric height measurements using the instrument transfer function," Proc. Fringe 2005, 30-37 (2005).

2:30 p.m.	F. Balzer, U. Gerhardt, T. Hausotte, E. Manske (D-Ilmenau)

Novel fibre-coupled reference sensor for nanopositioning and nanomeasuring machines

Over the past decade a trend of component miniaturization can be observed both in industry and in the laboratory, which involves an increasing demand for nanopositioning and nanomeasuring machines (NPMMs) as well as for appropriate miniature probe systems.
One challenging topic is the reference position of a NPMM, which is the position where the interferometric length measuring systems are set to zero. It has to be well defined because the interferometers are relative measuring systems and need an external reference point where their counters are set to zero. The dead-path length and its uncertainty directly influence the uncertainty budget for a specific measurement. To reach the ambitious goal of realizing an effective measurement uncertainty in the nanometre range over a large positioning range, this influence has to be minimized. To fulfil this demand, a novel fibre-coupled monochromatic reference sensor has been developed at our institute, which is introduced in this paper. This paper puts the emphasis on the system design of the fibre-coupled sensor and its metrological properties. The mechanical system and the electronic unit will be presented. In contrast to other systems serving as reference sensors, the big advantage of our system is, that the fibre-coupling prevents waste heat from the light source from influencing the measurement setup. This is of great importance especially due to the mounting near the interferometer axes. Furthermore it enables a miniaturization of the sensor head and thus facilitates the integration into the existing length measuring systems. The nanomeasuring machine NMM-1 is used to investigate the metrological properties of the sensor. Therefore, the sensor head is fixed onto a Zerodur plate used for mounting probing systems on the metrology frame of the NMM-1. As measurement object a cube made of Zerodur with reflective coating on its surfaces is used. The cube is placed on the corner mirror and is positioned with the stage in the z-direction. Some characteristic parameters, such as resolution, linearity and reproducibility, are investigated. The influence of environmental effects has been analysed to judge the stability and the applicability as reference sensor.

2:50 – 3:10 p.m. Coffee break

3:10 p.m.	A. J. M. Moers, E. J. C. Bos (NL-Eindhoven)

Design and verification of the TriNano ultra precision CMM

The target uncertainty of the TriNano CMM is 100 nanometer (k=2) over its measurement range of 64 cubic centimeters. This is achieved using an innovative concept of which the workpiece table is supported by preloaded air bearings. An important aspect is the stability of the air gap which is measured at different positions in the measurement volume using three capacitive sensors, placed around the air bearing.Operating principle In the TriNano, the workpiece moves in three directions with respect to the stationary probe by means of three identical linear translation stages. The stages are positioned orthogonally and in parallel and support the workpiece table via vacuum preloaded (VPL) air bearings. A linear translation of a stage is transferred via a VPL air bearing to the workpiece table. On each linear stage, the scale of an optical linear encoder is mounted. At the point of intersection of the measurement axes of these encoders the probe tip is located. As the orientation of the encoder scale does not vary with respect to the probe, the TriNano complies with the Abbe principle over its entire measurement range. The parallel configuration of the three identical stages supporting the workpiece stages results in superior dynamic behaviour of the TriNano. This configuration allows a low and equal actuated moving mass of each stage with short and stiff structural loops. On machine measurements show that the lowest natural frequency in the positioning loop is 75 Hz, allowing a high control bandwidth required for scanning measurements of micro parts with a velocity of 1-2 mm/s. Verification experiments The stability of the air bearing has been verified on the machine to take all possible disturbances into account. Three capacitive sensors have been positioned around the air bearing. This setup allows the direct measurement of the axial displacement and tilt in two directions of the workpiece table relative to the air bearing. The standard deviation of the air gap variation is 3 nm. It can thus be concluded that the air bearing are not a limiting factor for achieving the specified 3D uncertainty of 100 nm.

3:30 p.m.	E. Guliyev, Y. Sarov, Tzv. Ivanov, M. Klukowski, I. W. Rangelow, E. Manske (D-Ilmenau)

Quasi monolithic integration of Silicon-MEMS with piezoelectric actuators for High Speed non-contact atomic force microscopy

High-speed Atomic Force Microscopy (AFM) is actually a functional tool for studies of dynamical phenomena of biological and chemical objects in sub-second timescale. In order to increase the imaging speed, all dynamic components of AFM have to be optimized. This paper presents advancement in the development of a novel x-y scanner for high speed non-contact AFM. We developed a quasi monolithic integration of a silicon parallel kinematic mechanism (Si-PKM) with piezoelectric actuators. Decoupling of motion in x-y directions is realized due to novel Ω-shaped flexures. For the control of the stage motion we employed piezoresistive sensors integrated into silicon L-shaped guidance features. Due to the use of a push-pull actuation principle we obtained a large scanning frequency and a scanning area of 6x6μm^2 scanning area. The resonance frequency of the stage is about 26 kHz. The silicon stage facilitates fast quantitative imaging with high lateral resolution.

3:50 p.m.	Yung-Cheng Wang, Lih-Horng Shyu, Pi-Cheng Tung, S-Y Lin (TW-Yunlin), Chung-Ping Changa, (TW-Taoyuan),

A novel algorithm for the signal interpolation of the displacement measurement based on a Fabry-Perot interferometer

Current commercial interferometers reveal excellent measurement performances, because of its major advantage which enables the displacement measurement with the characterization of the high resolution under the large measuring range. Fabry-Perot interferometer is a compact interferometer with the structure of common optical path. In comparison with the ordinary commercial laser interferometers having non-common optical path, Fabry-Perot interferometer is more insensitive to environmental disturbances. But the disadvantages of Fabry-Perot interferometer are the limited measuring range and the considerable visibility decadence of the interference pattern. To enlarge the measuring range, the folded Fabry-Perot interferometer in which a corner cube reflector severs as the measurement mirror has been proposed in the previous research. However, either the conventional Fabry-Perot interferometer or the folded Fabry-Perot interferometer still have the problem of the considerable visibility decadence of the interference pattern. When the length of optical cavity is changed, the overlapped state of the laser beams will be varied strongly. Hence, it is indispensible to offer a proper signal interpolation algorithm for various signal distributions during the displacement measurement in the whole measuring range. An advanced signal interpolation algorithm for the above-mentioned Fabry-Perot interferometer has been proposed in this investigation. The novel algorithm is able to solve the problem of the displacement measurement due to the considerable visibility decadence of the interference pattern. With this algorithm, a high precision displacement measurement in the large measuring range can be realized by the folded Fabry-Perot interferometer.

4:10 p.m.	T. Machleidt (D-Ilmenau)

Area based optical 2.5D sensors of a Nanopositioning and Nanomeasuring Machine

The fundamental and innovative concept of the NPMM is the realization of the Abbe comparator principle in all three measuring axes [1] – that means that the measuring probe and the measuring beams of the machine must be aligned. This has the effect of avoiding systematic and random tilting of the guide elements, also called first-order tilt errors. The consequent observance of the principle has made possible a state-of-the-art nanopositioning and nanomeasuring machine with a resolution of 0.1 nm and a positioning repeatability below 0.3 nm within a measuring volume of 25 mm x 25 mm x 5 mm [2]. In contrast to conventional coordinate measuring machines the sample is moved instead of the sensor. Sensors are fixed in such that their working point is located in the Abbe-point. The displacement of the sample can thus be measured with highest accuracy. Besides the large effective range and the high resolution, a significant advantage of the device is that several different measuring methods can be applied. The different types of sensors are quickly and easily changeable because of their modular conception. So far atomic force microscopes, focus sensors as well as capacitive and inductive contact systems are applicable sensor types for the NPMM. However, data capture for these sensors is limited to one dimension; the measuring data can only be acquired sequentially point by point. This also means that the

measurement time requirements cannot ever be met. Parallel data collection is desirable, which is possible on the basis of white light interferometry or depth from focus, powerful optical measuring methods that allows the capturing of a whole surface with very high precision within a few seconds. The needful measuring hardware setup of the two measuring methods is nearly the same. To use white light interferometrie we need an interference objectiv and to use depth from focus we need a normal objective with a high NA value.

4:30 p.m.	F. Siewert, J. Buchheim, T. Höft (D-Berlin), S. Fiedler, G. Bourenkov (D-Hamburg), R. Signora (D-Bergisch Gladbach)

High resolution slope measuring deflectometry for the characterization of ultra-precise reflective X-ray optics

Slope measuring deflectometry has become a standard technique for the inspection of ultra-precise reflective optical elements for synchrotron applications. We will report on the inspection of ultra-precise adaptive synchrotron mirrors (bimorph mirrors) to be used under grazing incidence condition. The measurements were performed at the BESSY-II Optics Laboratory (BOL) of the Helmholtz Zentrum Berlin (HZB) by use of the Nanometre Optical Component Measuring Machine (NOM). The data obtained by the optical measurements are used to simulate the characteristics of the achievable X-ray focus by ray tracing calculations hereafter demonstrated for the case of the bimorph mirrors of the EMBL MX1 beamline for macromolecular crystallography at the PETRA III synchrotron at DESY (Hamburg).

Poster Session 1.1 Nanopositioning and Nanomeasuring Technology

Time: Thursday, 15.09.2011, 12:00 noon – 1:30 p.m.
Location: Foyer Humboldt Building

L. S. Ginani, R. Theska (D-Ilmenau)

A Novel Approach to Optical Aberrations Correction in Laser Scanning Microscopy for Surface Metrology

This article presents the design and construction of a laser scanning microscope for surface metrology. The proposed system is designed for using simple uncompensated optics in order to reduce overall costs and the weight of the movable focusing optics, therefore improving measurement speed and system dynamic and offering the possibility of system miniaturization. In order to overcome the effects of optical aberrations in the system caused by the use of simple optics, a new approach is proposed, where the effects of these aberrations in the measurements are computationally corrected.

D. Dorantes, B. Jin, M. Bai, F. Sun, X. Fu, Y. Li, Z. Chen, X. Hu (TW-Tianjin)

A Novel Circuit for Processing Faint Laser Generated Surface Acoustic Waves Based on Lock-in Amplification Technology

Currently, nanoindentation has been steadily used as the major commercial technique to measure Young's modulus and hardness of thin films and coatings. However this technique has still several drawbacks, for example, its results are obtained indirectly, and usually require a cross-validation with other techniques; the lateral resolution is limited by the indenter size; the reliability of results depends on special measurement conditions and undesired effects like creep and thermal drift, influencing the maximum depth and the gradient of the upper unloading curve; and testing is often destructive. Therefore, exploring a new method for determining thin film mechanical properties is a big concern.

Techniques based on laser-induced surface acoustic waves have been developed with the potential for characterizing the mechanical parameters of thin films, such as Young's modulus, density, thickness, etc. Therefore, Surface Acoustic Wave has been justified to be a feasible and promising technology. However, the limited spectrum bandwidth and low sensitivity of the Laser-Generated and Laser-Detected SAW method have restricted its further development**.** Therefore, to contribute to the significant improvement of this technology, we propose a weak signal processing circuit based on the Lock-in Amplifier, achieving detection of weak signals for such a GHz SAW detection system.

In comparison with the traditional LIA, there are significant improvements in the novel unit. First, in the reference channel, only one phase-shift circuit was used, which makes the circuit simpler, but still achieving the functions as a traditional LIA. Second, we use a noise-removal unit block and a voltage follower to substitute the preamplifier, which can remove most of the noise, and ensure the impedance match of the latter circuit. Considering that the amplitude of most of the noise is less than 0.2 V, a diode array before the noise-removal unit is set with a turn-on voltage of 0.2 V.

The experimental results showed that the denoising capability of the novel Lock-in Amplifier has been greatly enhanced, the output noise was reduced one hundred times, from 0.3 V to about 0.003 V, and the signal to noise ratio has been greatly enhanced, up to 460 times.

R. Rosa, S. Rizzuti (I-Rende)

A procedure to minimize points extraction for effective flatness measurement by CMM

Nowadays Coordinate Measuring Machines (CMMs) are generally employed in the industrial process, in order to check geometric tolerances on the parts produced or during the production process and so to verify if specifications, defined in design phase, have been satisfied. At the same time it is necessary to underline that CMMs have some drawbacks.
The measurement reliability is strictly connected to the number of points to be acquired and, at the same time, costs also grow rapidly with this. So it is important to trade off these two aspects. In order to limit uncertainty it is important that designers, manufacturers and metrologists subscribe to a protocol to check the geometric characteristics, avoiding that economic considerations (related to time and verification costs) could lead to the use of incorrect sample point sizes, unable to evaluate the real geometric error of the part correctly. The paper presents a procedure able to evaluate flatness error on real work pieces by means of Coordinate Measuring Machine. This kind of measurement requires or very large dimension of sample points in order to extract points in the zones of maximum heights and depths, while usually metrologists may not extract very large sample points because this is too expensive in terms of costs and time. The paper discusses a procedure that has been tested introducing in the pre-analysis the qualitative methodology generally used for flatness evaluation by means of Prussian blue. This treatment shows, in a quick and easy way, the zones on the surface where are located peaks and valleys and metrologist is so addressed to extract points from these selected areas. Then, in a sort of selective process, the best and few points, able to measure flatness error with sufficient accuracy, can be extracted over the surface. A really reduced number of points will be so sufficient to reach a high accuracy in the measurement of flatness, without previous knowledge of the manufacturing process employed to produce the work piece. The paper presents the results obtained about the flatness measurement on some test cases, in which the results obtained with the reduced sampling is compared with a reference value obtained with very high sample point size derived from a uniform sampling strategy.

E. Sparrer, T. Machleidt, T. Hausotte, E. Manske, K.-H. Franke (D-Ilmenau)

A framework for optical sensors utilizing I++DME on nano positioning and nano measuring machines

The scope of this paper is the implementation of a variable framework enabling the fast development of optical sensor systems for coordinate measuring machines, utilizing the standard protocol inspection plus plus for dimensional measurement equipment (I++DME). Since various principles of measurement exist for optical touch probing, each requiring a specific procedure of measurement, in 2003 the optical sensor interface standard (OSIS) was released as metrology standard and sensor integration guideline. The developed framework realizes the full OSIS standard and enables rapid and standard compliant integration of new sensor hardware for CMMs. After a short excurse to nanopositioning and nanomeasuring machines – on which the implemented framework was tested – OSIS and the framework's architecture are explained. For function validation the implementation of an optical white light interferometry sensor system based on the bare framework is presented. Utilizing this

OSIS sensor, measurements at a micro contour standard were carried out. The results are presented and tested against the samples calibration data.

O. Ivakhiv, O. Tkatchenko, R. Tkachenko, Y. Hirniak, P. Mushenyk (UA-Lviv)

Rule-based Fuzzy System of Improved Accuracy

There are a large number of the non-linear complex processes for nowadays, but in practice there are absolutely no its adequate mathematical models correct. It is the problem to create appropriate ones to be clear for user's correct simulation and the next appropriate movement control. Alternative rule-based fuzzy mode systems are the fuzzy models designed by the rules called fuzzy logic controllers independent to the way of implementation both instrumental and software emulators. It can be considered as both as some induction of interval models and classical algebra of logics. For nowadays-created fuzzy models the most used are two of them, i.e. Mamdani and Sugeno algorithms. The main preferences are corresponded with the model's transparency due to its linguistic interpretation and the possibility of the received expert's knowledge using. Remark, all existing fuzzy logic algorithms are not precise and its results in most cases depend on choices and assumptions by consumers. This considers great efforts to correct and balance fuzzy controllers.
Here we consider such task solving based on fuzzy logic software controller with neural set structures using of Geometrical Transformations with some differences of correction and operation ways. The important feature of such controller is the absence of the combining operation all rules, using fuzzy expansion OR (so called as s-norm). For such type controllers, unity of rules exists are not realized by fuzzy OR. It is formed by prediction using the taught neural set structure Geometrical Transformation with ideal data. We receive clear argument value at its output. The key feature of such way is as follows: if, hypothetically, the logic conclusions rules are absolutely accurate and absolutely precisely corresponded with fuzzyfication variable data, then methodical error of the clear output variable value will be equal zero. Also next specific feature is put in some changed form of the logic conclusions rules presentation, i.e. each rule is independent. Proposed T-Controller is a fuzzy controller which creates logical decisions for fuzzy logic system using a fundamentally new method of dephazyfication of zero methodical error. It makes possible verbal user description and applies it to digital data.

B. Lustermann (D-Nordhausen)

A simulation model for an optical-electrical combination conductor system "CONDUS"

Over the past few years the University of Applied Sciences Nordhausen investigates und develops the innovative optical-electrical combination conductor system "CONDUS". This invention is patented in many countries (in Germany under No. DE 103 42 370) and opens completely new fields for applications. The principal item of the optical-electrical combination conductor CONDUS is a combination of an electrical conductor (e.g. copper wire) with a coat of an optical polymer. The aim of this work is to present a simulation model for such conductors and to use it in order to investigate the influence of different designs, materials and geometries. The model is based on the ray tracing software FRED of the US-American company "Photon engineering". The development of the model and the investigations described below are part of a joined PhD procedure at the Technical University of Ilmenau and the University of Applied Sciences in Nordhausen.

Session 1.2 Measurement and Sensor Technology

Time: Tuesday, 13.09.2011
Location: Humboldt Building, Humboldt Lecture Hall
Chairman: K. Sommer (D-Braunschweig)

9:00 a.m.	H. Bettin, M. Borys, I. Busch, A. Nicolaus, P. Becker (D-Braunschweig)

The Avogadro constant determination for a redefined kilogram

Today the mass unit kilogram is still defined by the mass of the international prototype of the kilogram (IPK), which is a PtIr cylinder that can be damaged or even destroyed. Additionally, it was discovered that the mass of the official and national copies changed by about 50 μg during 100 years in comparison to the IPK. Thus, it seems that the IPK mass changes with time. This would result also in a drift of other units like ampere and volt.

Two experiments are favoured to prepare and to realise a new definition of the kilogram. First, a measurement of the Planck constant h by a watt balance. This method includes a virtual comparison of a mechanical power with an electrical power, which is measured by Josephson and quantum Hall devices. The second way is to define the kilogram by an exact number of the atomic mass unit. This is equivalent to define the Avogadro constant N_A, which is the number of entities in one mole or the number of atoms in 12 g of the isotope ^{12}C. Using measurements of the molar Planck constant $N_A h$, both ways are nearly equivalent, since the molar Planck constant is known with a relative uncertainty of about 1×10^{-9}.

In the International Avogadro Project a silicon single crystal grown from isotopically enriched ^{28}Si is used to determine the Avogadro constant using the formula

$$N_A = 8\, M / (\rho\, a_0^3).$$

In this method molar mass M, lattice parameter a_0 and density ρ of the crystal are measured. This yielded the new value of the Avogadro constant $N_A = 6.022\ 140\ 82 \times 10^{23}$ mol^{-1} with a relative standard uncertainty of 3×10^{-8}.

The presentation describes the measurements of the density of the silicon crystal by mass and diameter measurements of a nearly perfect sphere. The diameter of the spheres was measured by an interferometer and the mass of the spheres was measured by comparison to PtIr mass standards, which were calibrated at the BIPM traceable to the IPK. To determine the mass and the volume of the silicon single crystal core of the sphere, additional corrections for the influence of the surface layer had to be made.

9:40 a.m.	A.-L. Eichenberger, H. Baumann, B. Jeckelmann (CH-Bern-Wabern)

The watt balance route towards a new definition of the kilogram

The kilogram is the last unit of the International System (SI) still based on a material artifact, the international prototype of the kilogram (IPK), which is kept at the Bureau International des Poids et Mesure (BIPM). The comparison made in the last hundred years have clearly revealed a long term relative drift between the IPK and a set of copies kept under similar conditions. With the present definition of the mass unit, it is impossible to assign this drift to the IPK or to the copies (or eventually to both). Moreover, variations of the mass unit directly reflect on the ampere definition and therefore on the whole set of electrical units. Since the long term stability is one of the major conditions set on the SI base units, this

situation is no longer satisfactory and a new definition of the mass unit becomes a priority for the metrology community. A promising route towards a new definition based on fundamental constants is given by the watt balance experiment which links the mass unit to the Planck constant. Such a definition would not only allow realizing the unit of mass at different places at the same time but also improve the consistency of the SI and drastically reduce the uncertainty on a large number of other constant. All units depending on the kilogram such as the ampere, the mole or the candela will no longer depend on the behavior of a material artefact. Recently, the METAS experiment has produced a measurement of the Planck constant with a relative uncertainty of $2.9 \cdot 10^{-7}$. The realization of a new experimental setup is underway to reduce the uncertainty. After a general review, this presentation will focus on the METAS experiment and discuss the latest results.

10:20 a.m. - 10:40 a.m. Coffee break

10:40 a.m. | F.-J. Ahlers (D-Braunschweig)

The Redefinition of the Ampere

The ampere is one of the seven base units of the SI, the international system of units. Its definition is linked to mechanical units, especially the unit of mass, the kilogram. In a future system of units, which will be based on the values of fundamental constants, the ampere will be based on the value of the elementary charge e. This paper describes the technical background of the redefinition.

11:20 a.m. | J. Fischer, Th. Zandt (D-Berlin)

New Definition of the Kelvin and Determination of the Boltzmann Constant

The unit of temperature T, the kelvin is presently defined by the temperature of the triple point of water. Thus, the kelvin is linked to a material property. Instead, it would be advantageous to proceed in the same way as with other units: to relate the unit to a fundamental constant and fix its value. By this approach no temperature value and no measurement method would be favoured. For the kelvin, the corresponding constant is the Boltzmann constant k, because temperature always appears as thermal energy kT in fundamental laws of physics.

Since the establishment of the International System of Units (SI) in 1960, extraordinary advances have been made in relating SI units to truly invariant quantities such as the fundamental constants of physics and the properties of atoms. Recognising the importance of linking SI units to such invariant quantities, the International Committee for Weights and Measures adopted in 2005 a recommendation to prepare for new definitions of the kilogram, ampere, kelvin, and mole in terms of fixed numerical values of the Planck constant, elementary charge, Boltzmann constant k, and Avogadro constant, respectively.

Before proceeding, the present value of the Boltzmann constant k needs to be confirmed by several independent measurement methods. To encourage new determinations of the Boltzmann constant, the Consultative Committee for Thermometry (CCT) recommended "that national laboratories initiate and continue experiments to determine values of thermodynamic temperature and the Boltzmann constant". In response to the recommendation of the CCT, many projects are under way to measure independently the value of the Boltzmann constant. These are acoustic gas thermometry measuring the speed of sound, and dielectric-constant gas thermometry using audio-frequency capacitance bridges. Other

promising methods for determining the Boltzmann constant are Doppler-broadening absorption spectroscopy and measurement of electrical Johnson noise. The progress achieved so far and the potential of the methods by the time of the redefinition are reviewed.
12:00 noon – 1:30 p.m. Lunch

Session 1.2 Measurement and Sensor Technology

Time: Tuesday, 13.09.2011

Location: Humboldt Building, Humboldt Lecture Hall

Chairmen: R. Schwartz (D-Braunschweig), Th. Fröhlich (D-Ilmenau)

1:30 p.m.	R. Engel (D-Braunschweig), K. Beyer (D-Stuttgart), H.-J. Baade (D-Salzgitter)

Design and realization of the high-precision weighing systems as the gravimetric references in PTB's national water flow standard facility

PTB's 'Hydrodynamic Test Field', which represents a high-accuracy water flow calibration facility, serves as the national primary standard for the liquid flow measurands: volumetric and mass flow rate, respectively, and total flow measurement, i.e. the quantity of fluid (volume or mass) having passed a flowmeter. As core components, which predominantly determine the operation accuracy of the whole facility, it comprises three different-size dual-balance gravimetric reference systems: 300 kg, 3 tons and 30 tons. This type of gravimetric references was realized as a combination of a strain-gauge-based and electromagnetic force-compensation load-cell-based balance, in each case. Though each of these two weighing principles fulfils the individual accuracy requirements that have been derived from the total measurement uncertainty budget of the calibration facility as a whole, the electromagnetic force-compensation load cells reveal several advantages concerning linearity error, hysteresis error and sensitivity. In designing the calibration facility in accordance with the accuracy requirements, special emphases had to be placed upon the dynamics design of the whole weigh system, due to the high measurement resolution and the dynamic behavior of the weighing systems, which are dynamically affected by mechanical vibrations caused by environmental impacts, flow machinery operation, flow noise in the pipework and induced wave motions in the weigh tanks. Taking into account all the above boundary conditions, the design work for the weighing system resulted in a concrete foundation "rock" of some 300 tons that rests on a number of pneumatic vibration isolators. In addition to these passively operating elements, the vibration damping effect is increased by applying a control-loop-based pressurized-air-actuated level regulation whose damping effect is enhanced by 3-axis linear electric drives acting upon the weigh system's foundation. Those drives are part of three self-tuned level stabilization and vibration damping controllers, in combination with feed-forward signal paths in order to improve the dynamic response and stability of the weigh systems' operation.

1:50 p.m.	G. Wendt (D-Braunschweig)

Experimental investigation of liquid flows in different pipe configurations using improved LDA techniques

Nearly all types of flowrate measuring devices (flow meters) are affected by the flow conditions at their inlet section. So-called disturbed velocity distributions of non-regular shape, with asymmetries or swirls can lead to meter errors in unpredictable high order up to ten percent or more. Great effort is being made to develop and improve the methods for a profound and efficient investigation of the flow behavior over wide ranges of conditions and pipe configurations. The main goal is to find a suitable model which allows an explanation and – if possible – a prediction of the changes in the corresponding flow meter indications due to the specific flow conditions in front of or inside the meter. At present,

the main focus is directed to non-intrusive, optical methods and to water as the measuring fluid. The paper describes improved experimental set-ups and actual results of three-dimensional velocity measurements in liquid flows using Laser-Doppler-Anemometry (LDA). Initially, investigations are carried out inside pipes of circular cross section at different flow rates under different disturbed and undisturbed flow conditions. Corresponding technical solutions as well as the optimized LDA data processing, evaluation, and presentation are explained. In a second step, the LDA hard- and software is modified to be employable for a special application – the measurement of velocity distributions inside a multi-jet cartridge water meter. In both cases, beside demonstrative qualitative descriptions of flow patterns by various 2D- and 3D-diagrams, dimensionless parameters are defined to realize a quantitative characterization of the flows under investigation. Analyzing the results of a great amount of experiments, clear correlations between the defined parameters of the inlet flows and the water meters' behavior can be shown. Moreover, limiting values of these parameters are fixed the observance of which admits the expectation that the indication of a certain water meter will not significantly change in comparison with the undisturbed case.

2:10 p.m.	D. Jian, Chr. Karcher (D-Ilmenau)

Electromagnetic flowrate measurements using tandem Lorentz force velocimetry as a cross-correlation flowmeter

Lorentz force velocimetry is a non-contact technique to measure flowrates in electrically conducting high-temperature melts. It is based on measuring the Lorentz force acting on a magnet system. This force is proportional to the flowrate and the electrical conductivity of the melt as well as to the strength and spatial distribution of the applied magnet field. Various prototypes of such corresponding measuring devices, called Lorentz force flowmeters, have already successfully tested in industrial applications. However, in metallurgic processes; the conductivity is often unknown or hard to evaluate as it strongly depends on both temperature and composition of the melt. Moreover, in the present paper we demonstrate that an arrangement of two identical flowmeters, i.e. tandem Lorentz force velocimetry, can be used to determine the flowrate by purely cross-correlating the two force signals. Cross-correlation techniques are based on measuring the transit time of a tagging signal. In more detail, we measure the time-of-flight of vortex structures that are present in turbulent flow and passing the two flowmeters. With the separation distance between the flowmeters at hand, the mean velocity of the flow can easily be calculated. Our model experiments are carried out in the test facility EFCO (electromagnetic flow control loop). As a model melt we use the low-melting alloy GaInSn in eutectic composition. The facility consists of a closed channel with rectangular cross-section of height $\times$ width $= 80 \times 10$ mm^2. The melt flow is driven by a frequency-controlled electromagnetic pump based on rotating permanent magnets. Moreover, the facility is equipped with a Vives probe to measure the local velocity in the center of the channel and an ultrasonic Doppler velocimeter to measure velocity profile across the height of the channel. The data obtained with these measurement techniques are used to calibrate the tandem flowmeter. In the experiments we vary the rotation frequency of the pump and the separation distance of the flowmeters. Our model experiments show that the tandem arrangement is a powerful technique to determine the flowrate in turbulent liquid metal flow without knowledge of both electrical conductivity and the spatial distributions of the applied magnetic fields.

2:30 p.m.	M. Gramß, Chr. Karcher (D-Ilmenau)

Calibration of a Lorentz force flowmeter

In this paper we describe an overall calibration procedure for a Lorentz force flowmeter, a device for measuring contactless flow rates in electrically conducting fluids. We introduce the calibration set up for calibrating a Lorentz force flowmeter, the so called dry calibration experiment and the wet calibration facility LiTinCa. Moreover we discuss some results of the dry calibration experiment.

2:50 – 3:10 p.m. Coffee break

3:10 p.m.	J. Aguilera (D-Braunschweig)

Dynamic weighing calibration method for liquid flowmeters – A new approach –

Flow measurement technology is an important area of engineering, which has remarkably grown up in the past decades. This is because it represents an effective way to technically assure, that the amount of fluid being transported or traded through a conduit, agrees with the magnitude claimed by a measuring system or an individual. Moreover, it contributes to enhance the efficiency, quality, and safety in any industrial or scientific process, wherein the accurate determination of the flow unit is needed. Nowadays, this sector is mainly focused in the following tasks: the development of more precise flowmeters, improvement of liquid flow calibration facilities, and the implementation of new calibration methods, which can deliver more reliable and affordable flowmetering technology to the industry. At present, the PTB department of liquid flow is dedicated to the implementation of a new weighing calibration method, which allows the characterization of flowmeters in a shorter period of time. The motivation for carrying out this work is based on the current necessity from some flowmeter manufacturers and calibration laboratories, to characterize large amounts of flowmeters in a reduced time. All of this, with the benefit to lower the workload, energy consumption, and calibration costs. In order to attain such a short term calibration, it is required to quantify the flow unit several times during a single measurement run. Therefore, in order to do so, the measurand has to be determined under dynamic weighing and quasi-steady flow conditions. As expected, the issue of working under dynamic process conditions will eventually increase the measurement uncertainty of the calibrated flowmeter. However, this factor can be compensated by the fact that some types of flowmeters, and measurement processes do not demand the highest levels of accuracy. According to a comparison test carried out at different mass flow rates between the proposed calibration method and a reference flow standard, it was demonstrated that a mass flow measurement accuracy smaller than ±0,1% is attainable.

3:30 p.m.	H. Weis, F. Hilbrunner, Th. Fröhlich, G. Jäger (D-Ilmenau)

Mechatronic FEM-Model of a electromagnetic force compensated load cell

Balances based on the principle of electromagnetic force compensation represent the state of the art concerning uncertainty of measurement and achievable resolution. Due to many applications of these systems in industry and research, there is a strong interest in improving the performance in terms of speed and accuracy. Hence there is a need for

accurate models, describing the behaviour of the complex system to be optimized. In this paper a mechatronic model for an electromagnetic-force-compensated (EMC) load cell is presented. Designed in ANSYS®, the model consists of two modules: The mechanical behaviour of the load cell is represented by a FEM model. The electronic and the electromagnetic parts, consisting of position indicator, controller and electrodynamic actuator are implemented into the model as a set of differential equations via APDL (ANSYS Parametric Design Language). The achieved results show excellent agreement with measurement results, both for time and frequency domain. The derived model provides a powerful tool for the simulation and optimization of load cells in interaction with controller and measurement hardware. This model can be applied especially for the investigation of the influence of ground vibration and other higher order mode excitation. Optimization of the mechanical, electromagnetic and controller components can be performed using this model, as well as experiments to determine the sensitivity of the complete system to changes of environmental properties e.g. the stiffness of the support.

3:50 p.m.	Chr. Maier, M. Macdonald, D. Harrison (UK-Glasgow), W. Waidmann, W. Pannert (D-Aalen)

Aero-acousitcal Sound Source Tracking of a Flowed Cylinder with a Beamforming Code

A cylinder placed in an air flow in a wind tunnel with a defined Reynolds Number (Re) can cause a tonal noise in the backlash area of the cylinder. This phenomenon can be recalculated with an appropriate CFD software package. Also, by placing virtual microphones in a simulation of the flow, it is possible to have information about the frequency domain of the pressure signals gained [1].

With suitable signal processing, the location of sound sources in the flow domain is possible and a MATLAB® code was written to solve this particular task. Hence it is possible to process the microphone signals in a way that the beam patterns occur. This beam pattern consists of one main-beam in the middle for one sound source and smaller side-lobes beside it. This is called a directivity pattern and it points directly to the sound source. By this methodology, sound sources in flow simulations can be tracked.

Additionally, it is important to mention that the mesh for the acoustical simulation must be discretised very finely in time and in space. Hence the biggest cell size in the ROI is 0.1 mm. In this case the ROI is chosen at the cylinder wall and in the backlash region of the cylinder, because a sound origin is located in these regions.

In this paper, an insight to the MATLAB® code is given with examples of feasibility of the location of sound sources. Also, in addition to this, the mathematical theory is shown to include the preventive steps required to realise the MATLAB® code.

End of Lecture Session

Session 1.2 Measurement and Sensor Technology

Time: Wednesday, 14.09.2011

Location: Humboldt Building, Lecture Room 211/212

Chairmen: Th. Fröhlich (D-Ilmenau), A. Weckenmann (D-Erlangen)

9:00 a.m.	Th. Fehling (D-Göttingen), Th. Fröhlich, D. Heydenbluth, M. Geyer, R. Schüler (D-Ilmenau)

Vacuum Transfer System for Loading the Sartorius Prototype Mass Comparator CCL1007

The Vacuum Transfer System (VTS) is designed for fully automatic loading of mass standards into the Sartorius Prototype Mass Comparator CCL1007. The system enables the user to transfer weights from air to air/neutral gas, air to vacuum and back, as well as from vacuum to vacuum conditions. The VTS is directly connected to the mass comparator vacuum chamber via a high vacuum gate valve and can be evacuated independently of the CCL1007 if the gate valve is closed. Inside the VTS chamber a fully automatic transfer system receives the weights and transfers them to the load alternator of the Prototype Mass Comparator CCL1007.

9:20 a.m.	M. Schalles, G. Blumröder (D-Ilmenau)

Calculation of the Effective Emissivity of Blackbodies Made of Alumina

Blackbodies are sources of temperature radiation that are used for calibration of radiation thermometers. Their effective emissivity should be close to the ideal value of 1 to approximate an ideal Planckian radiator. Their effective emissivity depends on the geometry of their cavity and the used material. It can be estimated by measurements, but often it is calculated by numerical methods. For typical graphite blackbodies it was shown in the past, that high effective emissivities better than 0.999 can be reached. In this article calculations of the effective emissivity of a alumina blackbody are presented. Alumina is new material for blackbodies, with different radiation properties. Using two calculation methods (Integrative-Cavity-Method andMonte-Carlo-Method) the effective cavity emissivity for blank and coated alumina are estimated. It is shown that effective spectral emissivities up to 0.99987 can be reached.

9:40 a.m.	V. Mazin, V. Andrianov (RUS-St. Petersburg)

Transverse sensitivity of tri-axial high sensitivity accelerometers

Vector accelerometers are required to have fairly good space selectivity that, in turn, implies low transverse sensitivity. This requirement is essential for meeting tasks imposed by various fields of application, e.g. industrial seismology, seismic studies, and acoustic measurements. In this presentation, we discuss a possible solution of this sensitivity problem by exploring design of a sensor with bimorph piezoelectric plates and string suspension of an inertial element. This design, in principle, provides for high primary (longitudinal) and low transverse sensitivity. We will discuss addressing the problem through both, hardware design and circuit approaches. An additional side of the problem finds itself in a conflict between the principle task (assuring high primary and low transversal sensitivity) and at the same time providing for acceptable frequency band.

The latter, however, is never too wide when small accelerations are being measured. We will show examples of designs that are suitable for all three fields of application listed above.

10:00 a.m. | M. Pufke, F. Hilbrunner, Chr. Diethold, Th. Fröhlich (D-Ilmenau)

Precision and low cost position detection using capacitive sensor technology

Using the example of a precision balance, which depends on the electromagnetic force compensation principle (EMC-scale), the application of an alternative capacitive measurement method will be specified. Presently, the required position detection of an EMC-scale is handled with an optical position detector. It consists of a light source, a differential photodiode and a slit aperture. By use of a differential capacitor an alternative measurement system could be found. Furthermore different electrical circuits for the capacitive measurement were investigated. An integrated capacitive analog-digital converter was selected, which allows a high resolution measurement with a low cost component. In this context first experimental investigations took place with the help of a simple designed differential capacitor arrangement. It can be pointed out that the principle of capacitive measurement is suitable for use as a zero position sensor in an EMC-scale. The integrated circuit is characterized by a high degree of linearity over a wide measurement range and low noise behavior. A disadvantage is the limited dynamic by a relatively low update rate of data acquisition. Starting point for further considerations should be an optimized design of the differential capacitor arrangement, as well as an electronic circuit with higher dynamics for further control of the balance.

10:20 - 10:40 Coffee break

10:40 a.m. | G. Krapf, H. Mammen, G. Blumröder, Th. Fröhlich (D-Ilmenau)

Impurity Dependence of Industrial Suited Thermometric Metal Fixed-Points

Phase transition temperatures of high-purity materials are used for precision calibrations of thermometers. However, the phase transitions and the resulting fixed-point temperatures are influenced by impurities contained in these materials. Impurities in the range of a few ppm can cause deviations of several millikelvins. To correct this impurity contribution, the "Sum of Individual Estimates" (SIE) approach was established in terms of ITS-90 fixed-point cells. But this method can also be applied to industrial-suited, miniaturised fixed-point cells (MFPC) used in self-calibrating thermometers. This publication deals with the practical challenge of describing impurity-related temperature deviations using the SIE method. For this, the SIE is applied to miniaturised fixed-point cells filled with high-purity zinc. This includes comparative analyses by glow discharge mass spectroscopy (GD-MS) as well as mass spectroscopy with inductive coupled plasma (ICP-MS) to quantize the impurity concentrations in zinc. Furthermore, the element-specific, concentration-dependent temperature deviations are presented for the fixed-point material zinc. For this, binary phase diagrams, thermal calculations as well as experimental data were analysed to extract the according sensitivity coefficients. Beside this, results from SIE analysis of MFPC are presented and their uncertainties are compared. In this connection, practical limits of SIE methods are also identified and discussed.

11:00 a.m.	S. Augustin, H. Mammen, Th. Fröhlich (D-Ilmenau) K. Irrgang, U. Meiselbach (D-Geraberg)

Determination of the dynamic behavior of high-speed Temperature Sensors

Currently at manufacturers of thermocouples, development is being continued on thermometers especially suited for applications in the automobile industries. These thermometers must very quickly react to sometimes very large temperature jumps, which is where emphasis in design optimization with respect to small time-percentage characteristics has been placed. These sensors are applied in areas with large temperature gradients and high flow velocities. When using the thermometer in different vehicle models there were failures, for example by a tube or collar demolition, tearing the thermocouple wires or deflection of the thermometer ("banana effect"). To investigate the causes of the sensor failures and the elimination of error there is cooperation between the temperature measurement Geraberg GmbH and the Department of Process Measurement Technology, TU Ilmenau.
The static and dynamic parameters of these thermocouples according to the requirements must be taken into account, for example:

- time per cent characteristic value t90 in water < 1s
- temperature > 1150 °C.

In the lecture, first results metrological investigations of the dynamic behaviour in various media, as well as the results numerical calculations according to the method of finite elements presented. For more information on the temperature field and flow conditions in automotive engines to receive, in cooperation with the Department of Fahrzeugtechnik of the Ilmenau Technical University metrological investigations carried out with custom-designed multiple thermocouple and according to have.
Especially interesting is that by the temperature dependence of the material data in the large temperature range hysteresis effects when heating and cooling of the thermocouples may occur. Also shown is the dependence of the thermal conduction errors and the dynamic parameters of temperature field and the flow conditions in the engine compartment.

11:20 a.m.	V. Nazarenko, P. Mironova, V. Polubok (BY-Minsk)

Dynamic characteristics of resonators under the action of varying frequency

The transient oscillation theory has been a subject of numerous investigations in the field of not only radio engineering, but also in mechanics. The results obtained in radio engineering are also recommended for applying to the problems of vibration tests of mechanical systems. Here no strict restrictions are imposed on the field of application of these results. The analysis of the solution of the problem of transition of a linear system through the resonance has shown the following. The mathematical formulation of the problem in radio engineering coincides with the problem in mechanics. All the points of the dynamic amplitude-frequency characteristic (AFC) can be obtained depending on the frequency scanning rate for any resonator. In practice, the following parameters: displacement of the maximum of the dynamic characteristic relatively to the maximum of the stationary AFC, measurement of the maximum value of the dynamic magnification factor, expansion of the dynamic characteristic relatively to the stationary one, displacement of the dynamic characteristic relatively to the stationary one. The matters of calculation and construction of the spectrum

analyzers comprising electronic resonators and using the frequency-modulated testing voltage coincide with the problem of accelerated tests of products under the transient oscillation conditions because they require the definition of the same parameters of the dynamic characteristic. The results of this paper can be used for designing the spectrum analyzers to be calculated based on the dynamic AFC parameters at arbitrarily high excitation frequency scanning rate, if the rate is constant. The proposed formulae describe the real dynamic processes with good degree of consistency. When the quality factor and the reduced number of exciting oscillations in the resonance band of the article are equal to one another, the value of displacement of the maximum of the dynamic AFC and the maximum amplitude of the transient oscillations are not dependent on the frequency scanning law.

11:40 a.m.	F. Pollinger, K. Meiners-Hagen, N. R. Doloca, A. Abou-Zeid (D-Braunschweig)

Spectroscopic determination of the effective humidity for distance measurements in air

When measuring large dimensions length metrology is facing a fundamental challenge: relative measurement uncertainties in the order of 10^(-7) in an optical length measurement can only be achieved if the index of refraction can be determined to the same level of uncertainty. One parameter for the application of respective approximation formulae is the humidity of the traversed air. Conventional point-like hygrometers are only sensitive to the ultimate vicinity of the sensor. Approximations of the effective humidity for longer distances would therefore require a dense network of these probes, strongly limiting the flexibility and thus the applicability in geodesy or production control. for example. Hence, an alternative approach to determine the effective humidity along the whole path of the length probe was followed in this study. Based on quantitative absorption spectroscopy, two optical hygrometers with a combined range of several centimeters up to several hundred meters were realized. As a particularity, the long-range hygrometer was designed to be combined with optical distance meters. Both systems were characterized under well-controlled conditions. The experiments proof the capability of the concept with an agreement significantly better than 4 % relative humidity. This level of accuracy is necessary for the refractivity compensation in the order of 10^(-7) on a wider temperature range. Moreover, the optical hygrometers show in the experiments a quicker response to changes in the humidity then conventional sensor networks. The hygrometers were also deployed under uncontrolled conditions. The results of these experiments demonstrate the benefit of the application of optical techniques in comparison to conventional hygrometers. This research is in part funded by the European Community's Seventh Framework Programme ERA-NET Plus, under grant agreement 217257. The research was performed within the EURAMET joint research project 'Absolute Long-distance Measurement in Air'.

12:00 noon – 1:00 p.m. Lunch

A. Wagner, R. Theska (D-Ilmenau), A. C. P. Bitencourt, H. A. Lepikson, W. L. Weingaertner (BR-Santa Catarina)

Novel approaches to reduce the uncertainty of torque standard machines for small torques

The number of small torque applications is increasing continuously – in the industry as well as in the science. To ensure the function of these applications, the required torque should be known and should be realized with an appropriate uncertainty. This fact reinforces the need of a working traceability chain up to a primary torque standard for nominal torques in a range from 1 N·m to 10 mN·m with torque steps down to 1 mN·m. The achievable relative uncertainty of current torque standard machines (TSM's) for the small torque range is no longer sufficient, especially not for torques less than 100 mN·m. This paper deals with new promising approaches to reduce the relative uncertainty in TSM's significantly.

A. Chaykina, N. Gorbatenko (RUS-Novocherkassk), S. Griebel, L. Zentner (D-Ilmenau)

Directional Tactile Sensor Composed of Conductive Polymer for Monolithic Compliant Mechanism

Key words: conductive polymer, compliant mechanism, directional tactile sensor

In this article a principle of a directional tactile sensor for compliant mechanism composed of conductive polymer is presented. In the field of biomedical engineering and the human-machine interface a specific compliance of the applied technical system is an obligatory characteristic for task and/or security relevant functions, like prevention of injury. Compliant mechanisms can meet this requirement through the material applied, for example silicon, and/or their constructional design. In case a sensor system is required or desired, the composed sensor material should have similar mechanic properties so that it could effect the deformation behavior of the structure under external loads as little as possible. Conductive polymers have the described properties and consequently the potential to be used as sensor elements. In the present work the preliminary investigations were performed. The variation of the specific resistance of electrically conductive silicon was measured within different load cases. Then the conductive polymer was deposited on a hemispherical compliant mechanism consisting of non-conductive polymer. As an elementary principle solution to directional detection, two perpendicular cross stripes of the conductive polymer having four contact points at the endings and the one at the cross-way point were used. In each case the strip section between one ending and the cross-way point composed a stretch addicted resistance, which performed a half bridge with a reference resistance. If the strip section was stretched, a change of voltage was measured by using a multifunctional data recording module and was visualized by a LabVIEW program. The contact was detected by overrunning a deformation level of the compliant mechanism which depends on test frequency and voltage change-level. With our experimental setup we realized a principle of a directional tactile sensor for monolithic compliant structure. The structure thus sensored allows differ-

entiating eight 45° sections of direction within one plane. The preliminary investigations showed the ability to use the applied polymer as a compliant sensor material. In addition, the applied polymer can be combined with non conductive polymer. The objectives of further works are discussed at the end of the paper.

F. Schmaljohann, D. Hagedorn, A. Buß, R. Kumme, F. Löffler (D-Braunschweig)

Thin-Film Sensors with Small Structure Size on Flat and Curved Surfaces

The development of a fabrication technology for thin-film sensors on metallic substrates with flat and curved surfaces is presented. Physical vapour deposition (PVD) by means of a magnetron sputtering system is used to deposit an insulating layer and a following functional layer. This layer is structured by distinct photolithographic steps utilising a self-developed spray coating technique, 4-axis robotics with micrometer precision and a UV laser with a spot size below 10 μm. This highly flexible technique allows a rapid change of design to produce various sensor layouts in a short time. Besides the fabrication technology, there are two realised applications for thin-film sensor technology presented in this paper. Firstly, a tool wear sensor for rotating cutting tools, directly detecting the flank-wear land width and secondly, sputtered resistance strain gauges for force measurement.
Measurement results showing the potential of thin-film sensors are given briefly.

M. Henning, T. Almeroth, O. Kühn, G. Linß, O. Birli (D-Ilmenau), R. Weinert (D-Bad Berka)

Procedures for gauging of volumina at fuel stations

In this Paper the principles of measuring volumina of fuel delivered at fuel stations are shown. Used is a comparison measurement between the gauging device and the indication of the gasoline pump. The volumetric principle of measurement is the common principle for the attribute testing. It is tested if the error of measurement is within the Maximum Permissible Error (MPE) of 0,5% of the delivered amount. This attribute testing is the most important part for legal verification of gasoline pumps. Another principle is the gravimetric measurement. Within this Paper, a measuring device is shown, that allows the economically verification of gasoline pumps even with high viscous fuels.

Chr. Diethold, F. Hilbrunner (D-Ilmenau)

Force measurement of low forces with high dead loads

The presented measurement system enables the possibility to measure very low horizontal forces in the range of 1μN with additional high dead loads which are up to 7 orders of magnitude higher than the measurement force (10N). The measurement force is limited by the measurement range of the used weighing system (2.1N). The measurement force acts perpendicular to gravity, while the dead load is orientated in direction of gravity. A possible application is the flow rate measurement of conducting fluids by Lorentz force. The force measurement system works with the principle of electromagnetic force compensation.

During the work the measurement system was set up as well as a calibration system basing on a voice coil drive. By knowing the immersion depth of the voice coil in its permanent magnet the sensitivity is in every orientation the same. The calibration system works fine and forces of less than 1μN are reproducible. A main source of error which was investigated is the influence of tilting of the measurement system. Small tilting angles in the range of 1mrad causing measurement errors in the range of the resolution of the measurement system. Measurements have shown, that it is possible to measure the designated forces for smaller dead loads. The main problem are higher dead loads, here the linearity error increases but is also in a very good dead load to measurement force ratio.

Session 1.3 Precision and Optical Engineering

Time: Tuesday, 13.09.2011
Location: Humboldt Building, Lecture Room 010
Chairman: P. Kuosmanen (FIN-Espoo)

1:30 p.m.	A. Müller, N. Hofmann, E. Manske (D-Ilmenau)

Approaching nanometre accuracy in large plane mirror's profile deviation measurement

The interferometric nanoprofilometer (INP), developed at the Institute of Process Measurement and Sensor Technology at the Ilmenau University of Technology, is a precision device for measuring the profile deviations of plane mirrors with a profile length of up to 250 mm at the nanometre scale. As its expanded uncertainty of U(l)=7.8 nm at a confidence level of p=95% (k=2) was mainly influenced by the uncertainty of the straightness standard (3.6 nm) and the uncertainty caused by the signal and demodulation errors of the interferometer signals (1.2 nm), these two sources of uncertainty have been the subject of recent analyses and modifications. To measure the profile deviation of the standard mirror we performed a classic three-flat test using the INP. The three flat test consists of a combination of measurements between three different test flats. The shape deviations of the three flats can then be determined by applying a least-squares solution of the resulting equation system. The results of this three-flat test showed surprisingly good consistency, enabling us to correct this systematic error in profile deviation measurements and reducing the uncertainty component of the standard mirror to 0.4 nm. Another area of research is the signal and demodulation error arising during the interpretation of the interferometer signals. In the case of the interferometric nanoprofilometer, the special challenge is that the maximum path length differences are too small during the scan of the entire profile deviation over perfectly aligned 250 mm long mirrors for proper interpolation and correction since they do not yet cover even half of an interference fringe. By applying a simple method of weighting to the interferometer data the common ellipse fitting was able to be performed successfully and the demodulation error was greatly reduced. The remaining uncertainty component is less than 0.5 nm. In summary we were successful in greatly reducing two major systematic errors. The interferometric nanoprofilometer in this machine generation is a precision device for laboratory use, able to measure profile deviations of 250 mm long profiles with an expanded combined standard uncertainty of 2.5 nm at a confidence level of p=95% (k=2).

1:50 p.m.	M. Kuehnel (D-Ilmenau)

Automated Setup for Non-Tactile High-Precision Measurements of Roundness and Cylindricity Using Two Laser Interferometers

An automated setup for non-tactile high-precision measurements of roundness and cylindricity of ring gauges is presented in this paper. The aim is to overcome classical problems of tactile and radial roundness measurements such as the error influences of the used rotary table and the work piece alignment and thus to increase the accuracy and reduce the measurement time. To achieve those aims a double interferometer concept was chosen and combined with a measurement system for the work piece alignment, a high precision rotary table and an automated four-axes adjustment unit. The main alignment errors of the work pieces (e.g. ring gauges) such as eccentricity and tilting are either suppressed or directly

detected and consequently reduced by the automated four-axes adjustment unit. Due to the non-tactile measurement concept and the contactless energy supply of the four-axes adjustment unit, the radial run of the rotary table is not affected.

2:10 p.m.	A. Ivanov (RUS-St.Petersburg)

The dimensional control of object on a position of inflection points of the diffraction pattern

The method of an estimation of the object size on a points of inflection position a principal maxima of a diffraction pattern is offered. It is shown, that the method has high sensitivity to a size change of objects and allows to carry out measuring with a error up to 0.1 microns.

2:30 p.m.	Ch.-H. Chen, B.-Y. Lee (TW-Yunlin County), Y.-Ch. Wang, Ch.-H. Cheng (TW-Douliou)

Development of an assembly aid measurement system for the rotary axis in a tool grinder

For the precision tool grinding, the geometrical and dimensional errors of ground tools depend on the accuracy of the grinding machine, and the ground tool's features will have influence on the quality of workpieces processed by the tool. Therefore, elimination of error sources will be beneficial for the improvement of the grinding accuracy, and enhancement of products' quality for workpieces. The positioning accuracy in the linear and rotary axis is the basic requirement for a tool grinder. If a rotary axis is driven by worm and worm gear, indexing accuracy of the rotary axis will be determined by the assembly quality of the worm and worm gear. In order to enhance the indexing accuracy of the rotary axis, a measurement system aided for the assembly has been developed to realize the optimal regulation during the assembly processing of the rotary axis. The correlation between the regulation of worm and worm gear and the indexing accuracy has been investigated and error analysis of the rotary axis has been also performed. Distributions of the indexing error can be gained by the experimental analysis. The improvement of indexing precision can be verified by the comparison analysis between the rotary indexing error before and after compensation.

2:50 – 3:10 p.m. Coffee break

3:10 p.m.	S. Kurokawa (J-Fukuoka)

Micro Radial Grating Disk Manufactured by Nanoimprinting Technique for Transmission Error Measurement of Micro Gears

Micro gear is one of interesting micro machine elements for micro mechanisms in the next generation. It is used to transmit rotational motion in high accuracy without delay motion. In addition, the progress of microelectro-mechanical systems brings us the new stage of nanomanufacturing. Micro gears have also been manufactured in this process nowadays. To realize a miniature transmission system, measurement of gear accuracy is essential for evaluation of manufacturing errors, meshing status, and running performance.
In transmission error measurement, the rotational angle of the shaft of each gear is measured with a rotary encoder. For micro gear engagement, the center distance between a pair of gears is very small, so the rotary encoders have to be small as well as micro gears to avoid the interference between each rotary encoder and the rotational shaft of the mating gear side. This paper focuses on nanomanufacturing of a micro radial grating disk for a micro rotary enocder with a small diameter suitable for practical measurement application of micro gears. In addition, nanoimprinting technique is also applied to achieve low production cost per grating disk by reproduction with a single master mold in practical advantages.As a result, a radial grating disk for a micro rotary encoder were designed and manufactured with EB-lithography and photo-nanoimprint techniques aiming at practical application of micro gear measurement. The grating patterns, of which line width is up to 50 nm, were successfully manufactured homogeneously and accurately on the Si substrate. The nanoimprint process was also achieved successfully with the Si master mold. The result shows that it is possible to manufacture a grating disk of which diameter is smaller than 1mm and the number of gratings is at least 10,000 as mass production. The smaller grating disk than 1mm in diameter was also manufactured to the diameter of 250µm. To improve the resolution and accuracy of the rotary encoder, nanomanufacturing accuracy must be an important key. A rotary encoder has great advantages such as robustness against temperature changes, possible error compensation, and applicable self-calibration technique.

3:30 p.m.	K. John, R. Theska, T. Erbe (D-Ilmenau)

The Use of Deflecting Elements in Interferometric Applications – Advantages and Challenges

This contribution deals with the classification and characterisation of deflecting elements under the new aspect of their application in interferometric setups. Deflecting elements known from common imaging optics are generalised to basic mirror arrangements and evaluated with regard to their relevant transfer properties when used in interferometric measurements. A novel approach for the classification and systematisation of these elements is proposed, which focuses on the change in the optical path length and the lateral shift of the beam due to typically small displacements of the deflecting element. Insensitive and sensitive axes for these displacements are introduced as interesting approaches for novel metrological applications. The objective of this work is to show options for the use of those axes for the incorporation of deflecting elements in interferometric applications. The nature of the change of the polarisation of the measuring beam due to the deflection by a prism or mirror and its influence on the interferometric measurement is highlighted as well.

3:50 p.m.	D. Dontsov, W. Pöschel, E. Langlotz, W. Schott (D-Ilmenau)

Laserinterferometric Vibrometer for Micro Components

The ability to perform nanometer-precision metrology becomes more and more important today. In particular, the advancing miniaturization of mechanical, optical and electrical components makes high demands on metrology systems. Especially in automotive and consumer electronics, increasingly more and smaller sensors, actuators and mechatronic systems come into operation. These systems need to be characterized during all phases of product development and manufacture. Laserinterferometric vibration measurements offer some advantages, as they are non-contact measurements and thereby reactionless. Laserinterferometric vibrometers provide unique opportunities by measuring arbitrary rough surfaces with an extraordinary fine resolution with traceability of measurement results to the international length standard. The vibrometers of SIOS are based on the principle of fiber coupled Michelson plane mirror interferometers. For vibration measurements on arbitrary rough industrial surfaces, the optical setup of the interferometer head was adapted. For characterizing the dynamic behavior of micro components like the vibration of MEMS, membranes or AFM cantilever, such a vibrometer was integrated in a technical microscope. In combination with a USB camera and a x-y translation stage, high precision scanning measurements on micro components are possible. Special software, which gives the possibility of data acquisition and visualization as well as frequency analysis of vibration and script language, is available too. For all applications, where precise and non-contact vibration measurements are required, laserinterferometric vibrometers are useful tools. In combination with a microscope, determinations of temporal changes in positions of objects or surfaces with lateral dimensions in micrometer range become possible. The vibrometers are featured by the possibility of measuring arbitrary rough industrial surfaces as well as micro parts with high precision and high resolution. Resolutions better than 0,1nm and frequencies in the range of zero to 2 MHz can be obtained.

4:10 p.m.	S. Latyev (RUS-St.Petersburg)

Unification of optical and mechanical designs microscope objectives

End of Lecture Session

Session 1.3 Precision and Optical Engineering

Time: Wednesday, 14.09.2011
Location: Humboldt Building, Lecture Room 010
Chairman: R. Theska (D-Ilmenau)

9:00 a.m.	S. Linß, T. Erbe, R. Theska, L. Zentner (D-Ilmenau)

The influence of asymmetric flexure hinges on the axis of rotation

Flexure hinges allow a specific geometrical design of monolithic compliant mechanisms and their deformation behavior. In precision engineering especially prismatic flexures with lumped compliance are used. In this contribution, the potential of simple asymmetric flexure hinges to minimize the shift of rotational axis is shown.
The notch contour is described by different and with respect to the transverse height axis symmetric and asymmetric hinge geometries based on circular fillets and radii. For symmetric rectangular contours suitable corner fillets are determined with respect to low maximum stress values. Furthermore, the advantages of asymmetric hinge geometries regarding a reduced shift of rotational axis are shown compared to conventional contours. Based on the analysis of different approaches to define the position of the rotational axis the optimal radii of asymmetric corner-filleted and undercut contours in terms of minimizing the stress-deflection ratio and obtaining an increased precision of rotation are determined.

9:20 a.m.	N. Heidler (D-Jena)

Investigations on clearance seal units for moving elements in an ultra-high vacuum region

To enable a friction and stick-slip free feedthrough of a movement into a ultra high vacuum region, two possible options are investigated. The flexible connection can be realized using a contact-free seal unit comprising evacuation grooves and successional seal gaps.
Design option 1 uses a rotational-symmetric seal unit that comprises multiple seal gaps and according exhaustion grooves. This seal unit separates the UHV-region from the ambient pressure. The second design uses a simplified, rotational-symmetric seal unit with a single seal gap. This gap separates the inner ultra high vacuum region from the outer region with a medium to high vacuum. Regarding the conducted analytical results, both options are in general feasible. The experimental results verify these calculations.
The main restriction for design option 1 is the number of necessary exhaustion grooves and the related number of evacuation tubes and vacuum pumps e.g. three exhaustion grooves for a gap height of 50 μm. Evacuation tubes with an appropriate high conductance would require an accordingly large space within the vacuum chamber. This could lead to the minimization of the diameter of the tubes and hence to a lower effective pumping speed and a higher pressure within the inner area. Using more mechanical vacuum pumps could generate unwanted vibrations, which can be transmitted to the MBD. That could significantly influence the requirement of holding a stable position of < 10 nm over a time frame of 10 minutes. This would adversely affect the performance of the whole system. The main restriction of the design option 2 is the required HV in the outer area. This demands a vacuum compatible design and leads to a limited choice for guides, actuators and probes. The main advantages are the simple design concerning vacuum generation, the simplified fabrication of the sealing system and the prevention of disturbing vibrations, which makes this the favorable option.

9:40 a.m.	Ch. Schaeffel (D-Ilmenau), K. Gastinger (N-Trondheim)

Design of an interferometric test station for parallel inspection of MEMS

The paper presents the optical, mechanical and electro-optical design of an interferometric inspection system for massive parallel inspection of Micro-Electro-Mechanical-Systems (MEMS) and Micro-Opto-Electro-Mechanical-Systems (MOEMS). The basic idea is to adapt a micro-optical probing wafer to the M(O)EMS wafer under test. The probing wafer is exchangeable and contains a micro-optical interferometer array. A low coherent and a laser interferometer array are developed. Two interferometer designs are presented; a low coherent interferometer array based on a Mirau configuration and a laser interferometer array based on a Twyman-Green configuration. The smart-pixel approach for massive parallel electro-optical detection and data reduction is discussed. The mechanical design concentrates on the scanning system and the integration in a standard test station for microfabrication. First results of a test scanning platform are presented. The overall control concept is described.

10:00 a.m.	M. Sondermann (D-Ilmenau)

Lens Mounts in Optical High Performance Systems with Small Diameters

Optical high-performance systems with small diameters are a special group of optical systems such as those used in optical systems for mask and wafer inspection, high-resolution microscopy or specific laser applications. These systems are mechanically characterized by an outer diameter between 20 and 80 mm which is common for standard microscope objectives. An optical characterization is given by a high numerical aperture and an optical design for DUV/VUV applications. The optical performance with respect to the Strehl Ratio is well in excess of the diffraction limit (>95%). Future and partly current requirements for such systems cannot be met safely with the existing possibilities of technical realization. From this follows that there is a growing need for technological and constructive development. As part of the structural design of optical systems, the mounting of optical components with mechanical elements, for instance lens mounts and the connection of mounted optical components to more complex systems, such as objectives, take a central role.
The aim of this paper is to give a short introduction to the current stage of development on the implementation of these mounting applications followed by the propagation of current and future requirements. As an example for a group of new solutions to fulfill the given requirements a kinematic lens mount will be demonstrated. This lens mount is able to connect a lens with a holder under low mechanical stress. An optical surface error given by mechanical stress less than 8 nm will be shown on practical results.

10:20 a.m. - 10:40 a.m. Coffee break

10:40 a.m.	P. Kuosmanen, Th. Widmaier, J. Juhanko (FIN-Aalto)

Measurement of guideway alignment of an on-site grinding machine

The largest of the drying cylinders in paper machines are the Yankee cylinders with typical length of 4...6 m and diameter of 3...6 m. Because of the size and weight the cylinders are reground on-site. Typical surface temperatures of these heated rolls are 100...200 øC. This means that the operating environment during the grinding process is hot and moist. To avoid conical shape and pitch marks, the guideway of the grinder must be aligned with the cylinder surface. Alignment with a thin steel wire is commonly used method for guideway alignment in machine tools. In workshop environment, an alignment accuracy of 0.01 mm can be achieved when combined with optical microscope or micrometer. The alignment error can be seen in the measured displacement of the wire in relative to the moving carriage. Typically an optical micrometer has an accuracy of 2 æm. Normally the wire alignment can be used only for horizontal guideways. If the guideway is tilted, then sag of the wire will produce an error in the alignment measurement. The sag of the wire can be calculated with the catenary equation. The sag can be reduced by using thin wires and high tensile force. Also the wire length must be kept at its minimum. This paper discusses some of the aspects of the alignment of the guideway of on-site grinding machines with a thin steel wire. The expanded uncertainty of the sag compensation was calculated for a typical Yankee cylinder size. The wire length is 6ÿm, the wire thickness is 0.3 mm and the tensile force is 75 N. The tilt angle of the guideway is set to 60ø which is considered to be an average tilt angle. According to the calculations, the tensile force and mass of the wire are the only true uncertainty sources. The correction for the wire alignment is insensitive to measurement errors during operation, i.e. to position and angle measurement errors. This means that if the alignment measurement value can be calibrated, then the accuracy of the actual measurement can be maintained if the wire and the tensile force are not changed. The results show that the compensation of the sag of the wire is possible and a guideway alignment accuracy of ?0.010 mm can be achieved at almost any tilting angle of the guideway, if the accuracy of the optical micrometer is ?2 æm or better.

11:00 a.m.	S. Fraulob, J. Schirmer, St. Richter, Th. Nagel (D-Dresden)

Meshing behaviour of miniaturised plastic spur gears for power transmission using FEM

In spite of the fact that miniaturised plastic gears for power transmission are widely used in many technical fields today, dimensioning for them has not been standardised, and there is little known literature on the subject. This paper shows the geometric features and specialised performance characteristics of these gears. Meshing behaviour, tooth deformation, flank pressure, and tooth root stress will be calculated as functions of tolerance, load, and possible profile modifications. Furthermore, points will be made regarding transmission and friction behaviour. From this analysis, recommendations about the design of such gear pairs will be made. In summary, the main difficulty in the operating behaviour of miniaturised plastic spur gears used for power transmission is the large tooth deformation superposed with the single pitch tolerance. In the worst case, it results in a significant meshing interference at the beginning and at the end of the path of contact. Therefore, the tooth profile should generally be modified by tip relief for gears with modules m<1mm.
This modification hardly influences transmission error, but the meshing behaviour is greatly improved. This causes less wear on the gears and reduces noise.

11:20 a.m.	M. van Riel, E. Bos (NL-Eindhoven)

3D vibrating probe for measuring microfeatures with nanometer uncertainty

Reducing component size offers many advantages in both industrial as well as consumer applications. Besides the obvious benefit of size reduction other advantages of miniaturization include lower mass, less energy consumption, more functionality per unit volume and cost reduction. As components become smaller, the need for low uncertainty 3D characterization increases. In the last decade various high precision 3D measurement probes such as the Gannen XP by Xpress Precision Engineering have been developed and are currently commercially available. However, various effects limit the use of these tactile probes, in particular when measuring on the micro scale.The performance of tactile microprobes is in particular affected by the stylus stiffness. As longer and thinner styli are used to measure micro features, their stiffness reduces. In combination with the surface forces present on the micro scale this results in stick-slip, limiting the smallest measuring step during scanning. Secondly, the reduction in stiffness of the stylus decreases the measurement sensitivity. As the stylus stiffness becomes low compared to the probe suspension stiffness, the sensitivity decreases rapidly. In existing tactile microprobes these limitations result in styli with moderate aspect ratios. As a result the smallest probe tip that can be used is limited also. In order to overcome the limitations of tactile probes mentioned above, a 3D vibrating microprobe is proposed. The measurement principle of the vibrating probe is based on changes in its dynamic respons as it interacts with the surface of a workpiece. The probe is excited close to or at its natural frequency. Due to probe tip-surface interactions the oscillation amplitude, phase and resonance frequency change. These changes are registered and used as measurement signals. Employing this principle will result in no stick-slip during scanning measurements and the loss of measurement sensitivity for higher aspect ratio styli will be far smaller when compared to tactile microprobes. As a result, smaller diameter probe tips can be used. A vibrating microprobe will be able to perform measurements on high aspect ratio micro-sized features, such as holes with a diameter below 60-80 μm, and with nanometer uncertainty and repeatability.

11:40 a.m.	A. Smirnov (RUS-St.Petersburg)

A tolerance analysis of microscope objectives used the Monte Carlo method

12:00 noon – 1:00 p.m. Lunch

A. Frolov, St. Latyev, O. Vinogradova, A. Tabachkov, D. Frolov (RUS-St.Petersburg)

Choice of parametrical lines of focal lengths in objectives for a microscope

A. van Daake (D-Clausthal)

Requirement Based Workspace Optimization for Hexapod Positioning Units

This paper focuses on the simulative optimization of geometrical dimensioning for hexapod positioning units. The presented optimization aims at an improve-ment of the workspace while respecting given geometrical constraints (e.g. due to technical limits of the construction) and providing a minimum quality of considered properties (e.g. max. forces on the legs, min. rotatory freedom) over the whole workspace. For this purpose the definition of an optimal workspace is discussed and different evaluation criteria are set up and analyzed. The selection of evaluation criteria allows to represent the potential of the parallel structured positioning units very precisely and provides the opportunity to perform an intuitive comparison to serial manipulators. Simulation allows todetermine improved geometrical dimensioning based on several heuristic optimization procedures according to the respective requirements.

S. Ring, Ch. Schierz (D-Ilmenau), S. Schiermeyer (D-Wümbach)

Influence quantities on sensors at monitoring of UV radiation for water treatment, a field report

The application range of water disinfection with UV lamps has developed significantly during the last decade. For the technical application, only UV-C radiation is meaningful because of its disinfection effect. UV-C radiation (precise far UV: UV-C-FUV) is arranged in wavelength range 200 nm – 280 nm. The water treatment with UV radiation is a physical procedure. Compared to usual chemical procedures, no reaction products remain in the water. For controlling the disinfection efficiency, UV lamps are mostly monitored by sensors. For the supply of precise measurement variables from the UV sensors a series of influence quantities at the fixation of sensor properties must be regarded. With the help of empirical values along with application samples, current requirements to UV sensors shall be derived and developments shall be initialized as well as continued. For the following taxonomy 2 notional complexes are introduced.

1. Influences from the sensor environment, with derivation to the requirements of the sensor
2. Realization of the sensor requirements under influence of constructive and material possibilities

T. Djamikov (BG-Sofia)

Pin Hole Line Camera

The cost of the typical objectives currently in use in the modern cameras is comparable with the value of all the other componenets of the optoelectronic device. A possible approach for a cost reduction and simplification of the camera construction is design without lenses. Sensors with a large pixel area that have increased sensitivity and advanced microcontrollers should be used in order to build up a camera with minimum number of components and objective without lenses.This paper presents and describes optoelectronic solution of the task for sun detection and measurement altitude and currently illuminance. It is based on linear photoreceiver and non-transparent barrier with various shapes.

The characteristic of the light that is used during the analysis and calculations of the Pinhole objective is the streight line propagation of the light beam. If we have a object in front of the objective, the light beams that pass through the hole define reversed image over the screen. The system is build up of three major components – linear sensor from TSL family of TAOS Inc., Micrichip PIC18F4550 microcontroller and dot matrix LCD for a image and result visualization. The camera is supplied by two Li-ion batteries or through the USB interface cable. Power supply unit delivers +5V for the camera and includes batteries charging circuit. The camera has an optional connection to computer by serial interface USB. The device is designed as HID (Human interface device), so no additional drivers are required – it is automatically detected and recognized by any computer operating system that supports this type of devices. Camera control is realized with simple commands transfered through the camera pointer, returned by the operating system. There is additional application SW that makes possible visual presentation of the illuminance for every pixel and stores the data in a file for a consequent processing and analyse by other SW tools. The device has additional service mode for upgrade of the microcontroller's firmware.

T. Djamikov (BG-Sofia)

Sun altitude Sensor

The paper offers a detailed description of an optoelectronic sensor designed to measure the Sun altitude at any given moment and the associated illumination. The design solution is based on a linear photoreceiver and a non-transparent screen with different configuration.Basic principle of measuring the angle of surface illumination is the quantifying of the length of the shadow produced by an opaque screen with a certain height. The screen will also create a shadow over a certain pixel number and the signal coming from the photoreceiver will provide clearly identifiable dark and light sections. Part of the photodiodes feature intermediate level of tension; those are the pixels on the shadow's edge. The effect is to be observed when the shadow does not cover the entire pixels on the edge but only the end part. This circumstance is used in the algorithm for precise assessment of the shadow's edge as a part of the pixel. Another possible configuration is a slit in middle opaque diaphragm positioned in front of the photoreceiver. With the sun's angle different from 900 to the horizon, the bright spot moves away from the center position, and depending on its location the angle of the sunrays is calculated. The paper gives account of the performed analyses and calculations and presents the block-scheme of the realized technical solution. The latter provides for obtaining the numerical value of the sun altitude

angle along with the related illumination. Base component of the scheme is a PIC family microcontroller. The latter controls the sensor functions; the LCD display; the buttons and further communicates with a Personal Computer over the USB interface.

E. Lübbe (D-Leipzig)

Experimental Evidence for the Formula for Saturation

In 2007 the author proposed a new formula for the saturation.
The formula proposed by the author is in agreement with the verbal definition of Manfred Richter: Saturation is the proportion of pure chromatic colour in the total colour sensation. For the experimental verification we need visual scaling data of saturation assessed by subjects. Because good scaling data could not be found in the literature a new investigation has been accomplished. For this the Japanese colour system PCCS has been used. For each hue there are 14 saturation steps. Therefore, each subject had to position 12 * 14 = 168 colour charts on a given scaling area. At first the people who have to scale were introduced between the difference between chroma and saturation. For visual scaling lines were drawn on a middle grey background. So we get a scale from 0 to 100 % from the left to the right. On the top left we put the white chart as 0 %. This is the zero point of the scale. Under the white chart we place some grey and at least the black chart. The person now has to put the charts of the first hue on the grey paper. He has to imagine that it is possible we can have charts with more saturation as the charts in his hand. That means that the chart with the highest value of saturation is probably to be placed on a point under 100 %. The next step is that he puts charts with white in the colour on the scale. This was easy to do for the most people. Finally the charts with grey and black have to be put on the scale. This was not easy in all cases. After putting all charts of the first hue on the grey scale, we look on which lines they lay and write down the values in a table. The visual test was done after ISO 3664 for graphic industry with day light D50 and 2000 lux. The experiment shows that the proposed formula can be used for calculating saturation from the measured values Cab and L*. If we make a new space with the axes L, S+ and h we get a nearly symmetrical space. It is much more symmetrically than the LCh-space. The LS+h colours space is an interest space also for calculating colour differences.
To have a formula to calculate saturation is useful for designers.

Session 1.5 Image Processing and Quality Assurance
Time: Tuesday, 13.09.2011
Location: Humboldt Building, Lecture Room 204
Chairman: G. Linß (D-Ilmenau)

10.40 a.m.	M. Laurowski, Th. Kerstein, Ph. Klein, M. Weyrich, H. Roth, J. Wahrburg (D-Siegen)

One shot optical 3D Surface Reconstruction of weak textured Objects for an Agriculture Application

Optical 3D measurement is meaningful in numerous industrial applications. In various cases, the objects to be measured moreover contain only sparse or even no texture. Predestinated examples are agricultural products like peeled potato tubers as well as industrial repetition parts made of plastic or ceramic, such as housing parts or ceramic bottles. These parts are often conveyed in a wobbling way during the automated optical inspection. Thus, conventional 3D shape acquisition methods like laser scanning might fail. In this paper, a novel approach for acquiring 3D shape of weak textured and moving objects is presented. It is primarily intended for automated optical quality assurance in field of agricultural processing industry. To facilitate such measurements, an active stereo vision system with structured light is proposed. The system consists of multiple camera pairs and auxiliary laser pattern generators. The shape acquisition is performed within one shot and is therefore beneficial for rapid inspection tasks. An experimental setup, including hardware and software, has been developed and implemented.

11:00 a.m.	S. Holder, K. Xie, A. Göpfert, M. Rückwardt, G. Linß (D-Ilmenau)

Method for a robust search line based estimation of intensity edge width in blurred gray scale images for quantification of motion- and out-of-focus blur

This paper presents a robust method for the estimation of the edge width at contours in intensity gray level images to determine the grade of blur respectively motion and out-of-focus blur. There are several methods for estimating of intensity edge width, but a lot of them got as main problem a sensitivity to noise and for this reason large variances of the measuring results. The method bases on a histogram estimation of bright and dark level with respect to the noise followed by a scaling. Afterwards the scaled edge curve is fitted by Gaussian error function for a functional describing of the edge [1]. The fitted edge is following used for calculation of edge width described by Thomas principle used for lens quality estimations [2]. The functionality of the algorithm is evaluated with synthetically noised and realistic captures at different optical magnifications, exposure times and velocities of relative motion between camera and measuring scene.

11:20 a.m.	Ch. Ußfeller (D-Ilmenau)

Application of image processing for autonomous robots

For the task of object localisation for autonomous robots, an image processing system is applied. The essentials image decoding, color classification and image segmentation are covered. The Helmert transform is applied for robot localisation by matching image segments with a pattern model. The transform is adjusted to utilize additional data gathered

by the image processing. A comparison between the original and the modified transform is done.

11:40 a.m.	M. Stöckmann, H.-W. Lahmann, C. Brungräber, S. Gary, D. Sommer, M. Golz, M. Gräfe (D-Schmalkalden), P. Anacker, H. Freund, A. Müller (D-Meiningen)

Color-based High-Speed Recognition of Prints on Extruded Materials

1 Introduction

During the production process of extruded thermoplastic materials, like e.g. cables, piping systems and tubes, several risk factors influence the actual quality of prints. Therefore, real-time inspection and evaluation in terms of adapted high-speed image processing and subsequent pattern recognition is highly desirable.

2 System Description

A system is presented which is aimed at realizing test coverages of 100 %. Therefore, overall inspection of the cylindric surface has to be realized and as a crucial point processing in full production speed. For this the following components have been developed:

- Adaptive illumination,
- Mechanical object guideway,
- Multi-camera system,
- Hardware implemented pre-processing,
- Character recognition software, and
- Print evaluation software.

The illumination was realized by microcontroller controlled high-power LED arrays in order to adapt intensity and colour matching as well as to avoid specular highlights. To capture the complete radial surface, a multi-camera-approach with fast line scan colour cameras was utilized. Several pre-processing stages, e.g. color-space-conversion, were hardware-implemented on FPGA. Print evaluation is aimed at detecting repetitive defects indicating malfunctions of the printing device and to separate them from pseudo-defects due to small surface irregularities. In order to improve the overall computational time and to fulfil the real-time requirements a massively parallel computing platform based on 512 modern graphical processing units (GPU) was incorporated.

3 Conclusions

The adaptive system presented provides means for detecting and evaluating a wide range of print defects on extruded thermoplastic materials. High quality image acquisition under rough industrial conditions as well as image pre-processing and analysis in real-time of a high-speed production process has been implemented. Print defects like colour drift, mis-shaped characters, smudges, colour splashes, blurred prints, distortions are estimated.

Acknowledgments

This project was funded by the Federal Ministry of Economics and Technology within the research program "Central program for innovations to the mid-sized companies" under the project KF2284601HM9.

12:00 – 1:30 p.m. Lunch

Session 1.5 Image Processing and Quality Assurance

Time: Tuesday, 13.09.2011
Location: Humboldt Building, Lecture Room 204
Chairman: G. Linß (D-Ilmenau)

1:30 p.m.	T. Almeroth, G. Linß, O. Kühn (D-Ilmenau)

Lifetime prediction of smart meter

This paper deals with various methods to estimate the lifetime of smart meters based on lifetime distribution and determination of their lifetime parameters. Focal points in this article are accelerated reliability tests and accompanying registrations in order to describe and quantify failure behaviour. It combines well-known approaches of technical reliability by the consideration of a priori knowledge. It is shown that the Weibull analysis represents a helpful method for the lifetime prediction due to its universal character. To modularize this procedure regarding to product variety and shorter innovative cycles, it is necessary to identify the functional components (reliability structure) and to assign lifetime parameters with the aid of a morphological box.

1:50 p.m.	K. Weißensee (D-Ilmenau)

Uncertainty estimation of image-based measurements affected by motion blur

The paper describes a new automated approach to the uncertainty estimation of image-based measurements affected by motion blur. Due to the upward trend to the integration of quality assurance in production processes, image-based measurements are executed in motion or on motion-blurred units under test. In that context new requirements are made on the measurement process and the estimation of measurement uncertainty. The main purpose of this paper is to present the interrelationship between the motion speed during the measurement and the estimation value of the measurement uncertainty.

2:10 p.m.	I. Mozgova, R. Lachmayer (D-Hannover), O. Biloborodko, K. Kuzntsov (UA-Dnipropetrovsk)

Parameter estimation of mixture distributions using evolutionary modeling for evaluation of optomechatronic systems

Optomechatronical systems consist of mechanical, electronic and software components. Methods to evaluate the reliability of these systems have to take different fault mechanisms into account. In the present work a new approach of analyzing this challenge has been applied. To enhance the statistical conclusion validity for such experimental data processing, finite mixture-distributions and spline-distributions can be used. Practical application of classical mathematical statistics methods for a mixture-distribution estimation results in comparatively complicated computational procedures. Therefore, investigations of alternative approaches for an estimation of parameters are a highly actual. The problem of estimation of mixture-distributions consists of a multiextremal optimization problem. Here, classical parameter estimation methods strongly depend on initial values. One of the possible alternatives to solve the assigned task is to develop a suited artificial intelligence technology. In the present work approaches based on genetic algorithms (GA) to estimate parameters of the mixture of exponential and Weibull models have been investigated. The proposed approach was employed to estimate the mixture-distributions parameters on generated and experimental statistical data. The intervals of mixture's parameters for the generation of an initial population have been chosen according to experiential expert knowledge and the method of moments. As target (fitness)-functions the maximum of the absolute value of difference between empirical and theoretical distribution functions and maximum likelihood function have been chosen. The comparative analysis of selection, crossover and mutation operators' influence on the algorithm's operating efficiency has been carried out. This method of failure analysis was applied to 5 mm white LEDs under load conditions of 140 mA. The efficiency of the defined approach is confirmed by the results of statistical modeling and experimental research. The results can be used directly for a reliability analysis and provide a good initialization to accelerate convergence of the Expectation Maximization algorithm.

2:30 p.m.	M. Laurowski, Ph. Klein, M. Weyrich, P. Scharf, S. Stark (D-Siegen)

Use-Appropriate Design of Automated Optical Inspection Systems for Rotationally Symmetric Parts

Presently, there is still a lack of concepts and technical design guidelines for automated optical inspection systems for rotationally symmetric parts. This paper provides an approach to solve this problem and presents a design support method based on decision trees. In order to understand the capabilities a systematic review of state of the art in inspection methods has been achieved. Sub-problems are identified and systemized within the complex environment. Subsequently principal challenges and practical case applications on industrial products are described.

2:50 – 3:10 p.m. Coffee break

3:10 p.m.	A. Göpfert, M. Rückwardt, M. Vogel, M. Rosenberger, G. Linß (D-Ilmenau)

Comparison of quality characteristics for machine vision of two industrial cameras with different sensor mounting methods

In this paper influences to machine vision systems are analyzed. There are several components in machine vision systems like illumination, optics and camera. Especially the parameters of the camera and the influences to it have a high relevance. The influence of the geometrical configuration of the camera is high. Because cameras get cheaper and cheaper, it seems that tolerances and the quality of cameras will be worse. Within the research different cameras where tested. The difference between the cameras is marginal. Sensor and electronic components are the same, but one is low-cost and the difference in mounting the sensor to the C-mount-adapter. Here geometrical variations like offsets in X, Y and Z, but also rotations can distort the optical imaging and the image interpretation. The influences of this variance were analyzed. Because of the variance in Z (vertical) the scale is different. This effect is correctable in an easy way through scale-factor. Even the variance in X and Y of the sensor is correctable. The rotations along X, Y and Z are much more complicated. In the end of the paper the results of the measuring are used to rate the two camera systems. The criteria are multisided with economical and metrological aspects. In the end the optimal configuration for an application can be found.

3:30 p.m.	A. Tamelo (BY-Minsk)

Active microstrip modules for millimeter wave radiometer

The primary goal of passive systems of radiovision millimetric range is a formation of the radio thermal image of some area of space. Systems with multipath receivers allow to see during each moment of time all researched area of space entirely. The main task was a creation of system of radiovision of a millimetric range which consists of the two-mirror antenna and a receiving grid of this antenna allocated in a focal plane. Advantages of antennas in microstrip execution: very small thickness, the small size, small weight, low cost, high efficiency, simplicity of manufacture and setting. The most widely used printing antenna is antenna Bow-tie.The detector is constructed on the basis of the diode with Schottky barrier HSCH-9161 which is mounted immediately in the antenna and the RC-filter. The matrix has been made on the microstrip substrate of high-frequency material R04003C in the thickness 200 microns. The receiving antenna with connected to it elements of a matrix of the radiometer are mounted on two-coordinate device equipped with a force drive in azimuthal and uglo-seater planes. Operation of all systems of the bench in an automatic mode is supported by program automated management system, collection, handling and visualization of results of measurements in real time on the basis of PC and the software which supports a mode of the review of the given working field of vision.
Signals of elements of a matrix after their gain moved on testing system LabVIEW where final handling and the analysis of the accepted signal was led. Results of formation of images of the two-dimensional slit-type object fulfilled in the form of letter L, are received at different frequencies of the coherent highlighting radiation.

Thus images are received as at the same radiated frequency of illumination of 90 GHz, and as a result of summation of the experimental images for frequencies of 90,92,94,96,98 GHz. Substantial improvement of quality in case of the synthesized five-frequency images in which oscillation oscillations of brightness signals are considerably reduced is received and there are bright stains, characteristic for single-frequency images.

End of Lecture Session

M. Rückwardt, A. Göpfert, M. Schellhorn, M. Rosenberger, S. Holder, G. Linß, S. Kienast (D-Ilmenau)

A structured LED Multi linear light for groove measurement of a spectacle frame

Nowadays, eyeglasses are not only a vision aid, they also are fashion and design articles for the customers. The customer preference for various forms of spectacle frames grows and is served by the different frame manufacturers. This development leads to an increased effort for the production of adapted eyeglass lenses because of the huge range of the different designs and their manufacturing inaccuracies [1]. Therefore it is absolutely necessary to know exactly the coordinates of the ground of the spectacle groove for grinding the glasses well. One non-contact possibility is the triangulations principle. Therefore often a laser line generator is used. But also a structured LED linear light is possible. For this the linear light has to have a define width, brightness and sharpness. The linear light on the object, here the groove of the frame, is changed by its surface and is detected by a digital image processing [2]. If more information should be detected within one image a multi linear light could be used. Due to this also a structured LED based light source is an economically priced alternative to a multi laser line generator.

A. Mitsiukhin (BY-Minsk)

Segmentation of Dynamical Images by Means of Discrete Hartley Transform

This paper considers the problem of finding the parameters of motion of a segmental low-observable (covert) object of the image on the background of inessential details. In a number of applications such as robotics, industrial technical control, detection of surreptitiously moving military machines, detection of changes in the images having occurred between frames (used in special systems), etc., it is necessary to estimate the object velocity, direction of its motion and path traversed by it. It is known that such attribute as the object motion can be applied when performing the segmentation of dynamical images. It is proposed to perform the segmentation of dynamical images in the frequency domain by means of the discrete Hartley transform (DHT). Unlike the discrete Fourier transform (DFT), the Hartley transform is related to real transforms and, therefore, simpler computationally than the former. The principle of selection of the attributes by means of the DHT is illustrated. The sequence of dynamical images can be presented as projections of each frame. It is proposed to express this presentation through a linear combination of discrete functions of the basis of the Hartley expansion. Calculating the 1–D DHT of the sequence of counts of the projections makes it possible to determine the components of the object movement velocity. The transforms Hartley determine the spectral presentations in the system of the basic Hartley functions of the signals (projections). The maximum values of the spectral ratios are formed at the points with those numbers of the normalized frequencies, the coordinates of which are proportional to the object motion velocity.

Thus, if the distance between the pixels, shooting frequency and such attributes extracted from the image as the values of the coordinates of normalized frequencies, corresponding to the maximum levels of the Hartley spectral coefficients are known, it becomes possible to calculate efficiently the velocity of the motion of a low-observable (covert) object on the distorted image. The paper presents also the results of the analysis of motion of the object on the images distorted by the additive noise.

Topic 2:

Mechatronics and Ambient Assisted Living

Session 2.1 Mechatronic Systems
Time: Thursday, 15.09.2011
Location: Humboldt Building, Lecture Room 129
Chairman: Th. Sattel (D-Ilmenau)

1:30 p.m.	J. Quellmalz, R. Neugebauer, M. Walther, H. Schlegel (D-Chemnitz)

Simulation and control of a servo drive with oscillatory mechanics

Position controlled feed drives are state of the art in the fields of machine tools and production machines. Appropriate high-performance control systems are required for automating these systems. By now modern industrial controls of the class motion control or computerized numerical control provide the facility of integrated commissioning and parameterization of particular drive components and control loops. Finding optimal controller settings for a defined motion is the focus of actual research work. For providing reproducible results under constant system conditions modern simulation tools can be helpful. The paper deals with a simulation model of an industrial drive system implemented in MATLAB®/Simulink®. Based on the model of a permanent magnetic synchronous machine an industrial control system with pulse width modulation and a cascaded speed controller is modeled. The drive simulation is calculated discretely by the corresponding cycle times of the motion control system. A multiple mass approach is chosen for modeling the mechanical plant. The verification of the simulation model is based on a test stand, which represents a feed axis. A servo motor coupled with a linear ball screw drive moves a linear guided machine table, which can be loaded with different extra masses. In addition to the motor encoder (indirect measuring system), a linear measuring system for detecting the position of the machine table is applied. Thus, there is the possibility to detect elasticity in the mechanics and to validate their simulation accordingly. As usual, the current and speed controllers of the feed drive are configured as PI controllers. For the first step, the parameterization made by the industrial control on its automatic commissioning is used. The verification is discussed on the step response of the closed loop current and speed control as well as the speed of the guided table. Furthermore, the variation of a controller parameter is examined by the simulation and the transferability is backed up experimentally. Focusing on integration in virtual reality and simulation based parameter optimization the usability of the proposed simulation model is discussed.

1:50 p.m.	V. Böhm, K. Zimmermann, A. Jentzsch, T. Kaufhold, F. Schneider (D-Ilmenau)

An approach to compliant locomotion systems based on tensegrity structures

Tensegrity structures are prestressed compliant structures composed of a set of disconnected rigid compressed elements connected by continuous prestressed tensional elements. A spatially limited, local impact on tensegrity structures yields a global change of their shape. This essential property initiates the development of novel compliant locomotion systems with large shape variability and simple system design. This paper presents new concepts for locomotion systems based on tensegrity structures. Selected basic design principles for locomotion systems based on tensegrity are discussed focusing on possible actuating schemes and simple geometric configurations. In the contribution three

locomotion systems (prototype A,B,C) based on tensegrity structures are presented. In contrast to the known approaches the considered systems differ in their actuation / locomotion schemes. As a first example, a tensegrity structure with a simple and functional shape and manifold shape variability is discussed. The system performance is verified by experimental investigations by means of a prototype of the tensegrity class 2 (Prototype A). Prototype B is a 3D class 1 tensegrity structure, based on two curved struts. The prototype demonstrates, that rolling locomotion is possible with tensegrity structures. The movement of the system is induced by internal mass displacements. The locomotion system - prototype C is based also on a 3D class 1 tensegrity structure with minimal number of struts. In contrast to the known solutions, the shape change is realized through direct force transmission between the struts. The locomotion is vibration induced. A complex mode of vibration of this prestressed compliant structure can be induced by dynamic electromagnetic excitation. By proper design, the mode of vibration can be varied in a wide range in dependence of the driving frequency. The use of this effect allows the realization of locomotion systems based on tensegrity structures with simple design and frequency controlled variable movement performance.

2:10 p.m.	S. Frank, F. Schale, Ch. Ußfeller (D-Ilmenau)

Odometry for mobile Robots with Laser Sensors

Autonomous mobile robots are dependent on systems for measuring covered distance to determine their actual position. Basically we are able to divide such systems broadly into two groups: First, in systems that rely on external references such as landmarks or GPS, and secondly in systems which collect robot-internal information, such as incremental wheel sensors. The soccer robots which are developed in the Department of Computer Application in Mechanical Engineering and the Department of Technical Mechanics at the Ilmenau University of Technology are representatives of the RoboCup Small Size League. They use measurement systems of both categories. Content of the article is the description of developing an additional measuring system on the basis of optical mouse sensors, which should increase the accuracy of determination robot position. Besides the technical aspects of the implementation of a sensor network consisting of three single sensors, also mathematical problems with respect to the analysis of measurement results, well as finally, first results of a previously realized prototype will be discussed.

2:30 p.m.	K. Röbenack, J. Winkler (D-Dresden)

Direct Simulation of Mechanical Control Systems Using Algorithmic Differentiation

A method for direct simulation of mechanical systems is provided which makes use of the algorithmic differentiation package ADOL-C avoiding symbolic or numeric calculation of derivatives. A framework is proposed which makes this software package available under MATLAB/SIMULINK for straightforward simulation purposes. The usefulness of the approach is illustrated by the example of Euler-Lagrange control systems.

2:50 – 3:10 p.m. Coffee break

3:10 p.m.	J. Machado, P. Borges, E. Seabra, L. Ferreira da Silva (P-Minho)

A Formal Approach for Aerospace Systems Control Considering SFC Specification and C Programming Language

The C programming language is one of the most used in critical embedded real-time controllers applied at aerospace systems. Despite its potential, it is a very general language, with many maintenance problems and with a little or without graphical structure. The absence of formal verification techniques - even if it is possible to find some works associated to C programming language formal verification - is a fact. In this paper, it is proposed a methodology, that is divided in two main steps, and has, as main goal, to obtain safe C program code from a SFC specification: in first step some tools and techniques are used in order to assure the quality of the SFC specification and, on the second step, the goal is to translate (in a systematic way) the safe SFC specification to C code considering crucial aspects like taking into account aspects related with time specification.

3:30 p.m.	A. Zelei, L. Bencsik, G. Stepan (H-Budapest)

An Underactuated Modular Robot for Testing Control Algorithms

In this paper we propose a concept of a modular robot that can mainly be used for testing control algorithms in research work and in education. In our research work the main purpose is the experimental testing of computed torque control algorithms of underactuated dynamical systems, which are modelled by non-minimum set of descriptor coordinates. A system is underactuated if a dynamical system has less independent actuators than degrees of freedom, it is underactuated. In general the application of the computed torque control leads to a differential algebraic equation system.Multibody systems, cannot be efficiently modelled in the most common way, when a minimum set of generalized coordinates is chosen. Instead, redundant set of descriptor coordinates can be used with geometric constraints, in order to avoid numerically expensive computations. Because of the geometric constraints between the redundant coordinates, algebraic equations arise in the resulting equation of motion. Several methods are known being able to handle control systems incorporating these phenomena. Before the application of these methods on complex robotic structures experimental testing on simpler robotic systems is also needed additionally to the simulational tests. The benefit of the development of a customized modular manipulator is to get a flexibly programmable and reconfigurable robot which can be built up in several various architectures. The modular structure makes possible to build up different configuration robots, including serial and closed kinematic chain robots. The design and tune of a control strategy for complex and often underactuated systems require practical knowledge and experience of sensing, actuating and data processing based on computers.

This predictably low price application makes possible to investigate the control of a serial, parallel or hybrid kinematic chained robot in real environment for educational or research purposes. Another important task is the portability and compatibility, which means that the system will be able to be mobilised easily and to be controlled by any PC using commercial softwares like the Matlab.

3:50 p.m.	A. Bulgakov (RUS-Novotscherkassk)

PC-based Control of Parameters for Automotive Automatic Transmission

Analysis of the tasks of monitoring and diagnosis of automatic transmissions determined the choice of the overall architecture of the stand diagnosing automatic transmission, which is implemented in three levels of microprocessor architecture. This stand on a PC is a universal mechatronic device with automatic monitoring and diagnosis, functionally-oriented instrumental in ensuring the management of automotive automatic transmission parameters of all types and brands. An important task to be solved by the proposed stand is the problem of effective analysis and characterization of signals, including a priori unknown, in the presence of noise of various nature. For data processing, an algorithm that meets the criterion of minimum risk, and reduces to an iterative formula, which uses the optimal single-step algorithm (algorithm Yazvinskogo). This algorithm is characterized by an increase in the number of diagnosed parameters automatic transmission, universal use, as in stand conditions, and in-service automatic transmission, increased accuracy, speed, reliability, with minimum complexity of the program.Automatic continuously records (ACS) a wide range of characteristics (including resources) for each automatic transmission (unique in its parameters). There is a short-term build additional units and changing the structure of automatic transmission, which significantly reduces design time and modernization. Comprehensive definition of parameters for high reliability of the information on the status of automatic transmission in operation, whereby the first time become possible to create sufficiently accurate models of the automatic transmission, allowing them to determine both qualitatively and quantitatively the variation of its parameters. At the same universality SKD Auto enable you to apply as it serves as well as non-performing automatic. Diagnosing the condition of a modern car with a promising new generation of automatic transmission control systems requires the study of complex processes and phenomena occurring in them.

4:10 p.m.	T. Petrov (BG-Sofia)

Automated cell-feeding device for cell microinjection robot

The paper presents the design of an automated cell-feeding device. The purpose of this system is to deliver a single immobilized cell into the working area of the pipette of a microinjection robot. The feeder has a cell-substance-providing unit that takes a single cell out of an aqueous living solution. Then the cell falls into a cell-immobilization unit. The cell is held inside a micro-well with a vacuum pump. A linear movement on the immobilization dish puts the cell under the injector pipette. The microinjection takes place. A visual feedback is used to decide if the cell is destroyed or not. Depending on the result – the cell is either thrown away or put into a container for further growing and analysis.

The mechanical construction of the system is built of transparent polymer. This choice is done for several reasons: a neutral chemical reaction to the used solutions; a possibility for constant visual feedback of the ongoing processes; easy replication of the parts through injection moulding for mass production of the device. The precise and autonomous operation of the system is guaranteed by a dedicated real-time embedded system that controls the processes of cell transportation, immobilization and extraction.

The system can work in stand-alone mode (a control sequence is repeated without external trigger) or in slave mode - the control system of the microinjection robot is generating high level commands.
End of Lecture Session

A. Bulgakov (RUS-Novotscherkassk)

SCM-logistics, and mechatronics systems for ensuring the smooth construction process

The influence of the Internet on the efficiency of business activity has resulted in making selling goods with decision making concerning planning projects, their implementation, material shipping and handling all the supply chain through the "Portals of Intelligent Logistics". The key to understanding the "Intelligent Logistics" is the "Intelligent Agent Concept". The basic feature of the second generation multiagent logistics is replacing the bar code with electronic markers, each of them containing an agent. This kind of commodity coding will enable to develop mechatronic systems for monitoring and material handling through the delivery process from the supplier to the construction site. These mechatronic systems based on the multiagent structure to control business processes within the ERP system will incorporate the following elements:

- Intelligent distribution of goods on the shelves (in warehouses).
- Intelligent robots capable of searching goods according to the data read from the intelligent codes, unlike conventional robots which can just deliver a commodity to a definite point.
- Intelligent transport systems (lorries, stand-alone means of transport, conveyors) capable of determining the kind of goods contained in them and transmitting this information further along the system if necessary.
- Intelligent systems designed to control the environment of storing goods and which a capable of detecting the proper conditions for storing each of the commodities.
- Intelligent commodity sorting systems that can sort out commodities in accordance with the data recorded in their codes.

In order to control information and resource flows of mechtronic production system considered above a team of five agents can be organized responsible for planning, maintenance, operation, safety and administration, each of them being a miniature system with knowledge base which functioning can be represented by three stages: setting a goal, receiving results, evaluating operation effectiveness.

A. Bulgakov (RUS-Novotscherkassk)

The Mobile Robot for a Building Site

Planning of moving of the mobile robot is the major problem of functioning independent robotic systems and one of the most actively researched areas of modern scientific - practical knowledge. The decision of a problem of planning of moving of the robot the computing geometry, computer modelling and the theory of automatic control covers the questions connected to such scientific areas, as an artificial intellect.

The purpose of operating of the mobile robot is maintenance of its moving on a desirable trajectory of movement when it follows on a planned way according to managing influences. The majority of the researches devoted to a problem of planning of moving of the robot without collision with obstacles in its way on the basis of application of neural net-

works and indistinct logic, were carried out in conditions of a known environment. Function of planning forms a highest level of a control system which procedures should differ at navigation in the determined and not determined environments. Consecutive management coordinates and supervises correct performance of requirements of function of planning and provides reaction to conditions of mistakes. Thus, it forms the central function of a control system. Operating of movement transfers elementary functions of movements, in view of kinematic and dynamic opportunities of the chassis of a platform of the robot After the end of positioning of the robot in system of coordinates of a technological site the binding of multiagents to system of coordinates of the robot is carried out. With the help of the rotating laser head the robot "interrogates" the located multiagents. Thus the system fixes position of a corner of turn of head and time of the response of the agent t, defines distance up to the aim a. The system calculates position of each multiagent concerning system of coordinates of a technological site through a binding of system of coordinates of the mobile robot.

M. Küster (D-Selb)

Simulation based Tolerancing of Electromagnetic Actuators

Present paper shows an approach to take tolerances into account within the first cycles of the design process of electromagnetic actuators. The different types of tolerances that can occur in solenoids are analyzed and classified. The principle strategy is outlined and illustrated by the example of a pot magnet. Primarily the dimensions of the pot magnet are optimized with respect to a minimum volume and the required forces. The achieved sensitivity for the optimum is calculated and evaluated. Based on this, the sensitivity is set as a further restriction in the optimization algorithm and reduced gradually. Hereby a robust design is found which satisfies the boundary condition. The trade off between the volume of the actuator and the achieved sensitivity is presented. After robust optimization a tolerance analysis is performed. The required tolerances on dimensions are determined according to the ISO tolerance grade system (DIN ISO 286). The tolerance analysis can be done either through a Monte-Carlo simulation or an approach based on sensitivity. Both possibilities are compared for the pot magnet, and the key points of each procedure are shown (number of samples, interaction). With regard to small variances in force behavior and minimized production cost, the IT (=international tolerance) grade for each dimension can be linked with a cost-tolerance function. To obtain a predetermined variance in force for a defined working point, a cost minimization is performed. The result is the optimal tolerance grade for each dimension found in terms of low production costs.

N. T. Pavlovic, N. D. Pavlovic, M. Milosevic (YU-Niš)

Design of Compliant Slider-Crank Mechanism

Compliant mechanisms gain some or all of their mobility from the relative flexibility of their joints rather than from rigid-body joints only. In this paper the new design of the compliant slider–crank mechanism with film joints, as well as the new design of compliant Scott-Russel mechanism (the isosceles slider–crank mechanism), have been presented. Compliant slider–crank mechanisms have been developed as counterparts of the rigid-body slider–crank mechanisms. The influence of the "length" of the film joints, the influence of the rigidity ratio (the ratio between the width of relatively rigid segments Wr and the width of relatively

elastic segments We), the influence of initial (undeformed) position of the mechanism (defined by the angle of the "input crank"), the influence of the "input crank" length as well as the influence of the input force acting point location on the guiding accuracy have been analyzed. The optimal dimensions and parameters of the compliant Scott-Russel mechanism with film joints have been determined in order to obtain the best guiding accuracy (minimal deviation between exact rectilinear and realized path) of the "coupler" point on the path segment length of 5 mm. The best guiding accuracy (minimal deviation of 0.075 mm) has been provided by the compliant Scott-Russel mechanism with the greatest "input crank" length, with the angle of the "input crank" of 0.44 rad defining the initial (undeformed) position of the mechanism, with the rigidity ratio Wr / We = 3, with the smallest "length" of the film joints as well as with the input force acting on the slider. Also, we have analyzed the mobility of the compliant Scott-Russel mechanism for the dimensions and parameters of mechanism providing the best guiding accuracy. The limit positions of the guided "coupler" point, determined by permissible maximal bending stress, enable maximal realizable displacement of the giuded "coupler" point of 55.38 mm with guiding inaccuracy of 2.007 mm. Respective maximal acting force causing appearing of maximal permissible bending stress has been 1,917 N. Guiding inaccuracy of the "coupler" point less than 0.100 mm can be obtained for the rectilinear displacement of the "coupler" point less than 6.5 mm.

M. Issa, L. Zentner (D-Ilmenau), D. Petkovic, N. D. Pavlovic (YU-Niš)

Embedded-Sensing Elements made of Conductive Silicone Rubber for Compliant Robotic Joint

This paper presents a new compliant structure for robotic joint mechanism with sensor elements made of conductive silicone rubber. Since the collision safety is important in many robotic applications, the joints should exhibit a low stiffness when subjected to the collision force in order to absorb this force. If such a joint has the ability to determine the rotation direction of its members during the collision, it will be possible to stop this collision or at least to minimize it. For this reason, we attempt to demonstrate a compliant mechanism with sensor elements which have two additional functions. They can work instead of springs to ensure the elasticity, and instead of dampers to absorb the unreasonable external collision force. Therefore this mechanism presents one type of safe robotic mechanisms with an internal measuring system. The sensor elements are made of carbon-black filled silicone rubber and produced by press-curing. Various compression tests are executed on the sensor elements. The sensor elements cannot be used for accurate measurements because of their strong non-linearity. In this paper a new way of detecting the direction of the robotic joint rotation is shown when an external collision force tries to prevent the rotation of the joint. The method of examining the concept of this compliant mechanism is tested experimentally.

A. Bulgakov (RUS-Novotscherkassk)

The dynamics of the flying robot based on quadrocopter

In recent years the pace of development of UAV systems are gaining momentum. Their properties, such as: mobility, high maneuverability, low noise level allows them to be indispensable when it comes to situations where you want to maintain surveillance of the state structures, the situation in the destroyed and burning buildings, and other adverse and

specific conditions. Quadrocopter based unmanned aerial robot has high maneuverability due to small mass. Propulsion system of the quadrocopter has low inertia, which allows it to be very sensitive to the control actions of the operator. However, in windy flight conditions, the low quadrocopter mass reduces its stability, and without special options for maintaining its position in the air, he may lose control and crash. Without special control its movements is difficult to do without the jerks and dangerous rolls of the robot. Due to above properties of the quadrocopter one should consider it as a dynamic object and take into account the nonlinear properties and the properties of its motor parts, consisting of rotor, gear and propeller in order to develop a stability control system of the quadrocopter during autonomous flight. In physical modeling uses information about the physical properties of the controlled object. To be able to fully simulate of quadrocopter we need to divide a complex model for two simplified parts. The first model reflects the properties of a mobile robot aircraft when it is subjected to altitude regulation and other – for angular control of quadrocopter. Two models will be considered separately in this chapter. In order to reduce the sensitivity of quadrocopter actuators to external influences and to reduce its vibrational apply the Kalman filter. Using block Kalman Filter, make up the structure of the altitude control system of quadrocopter. Based on the results of modeling can tell that the Kalman filter has a significant positive impact on the assessment of the system even at very noisy. The system becomes more resistant to interference and noise.

R. Huber, K. Röbenack, St. Zipser, S. Wagner (D-Dresden)

Fault-tolerant track estimation algorithm for truck-trailer vehicles

In order to increase the transportation capacities and reduce energy consumption long articulated vehicles consisting of a driver-controlled truck with one or more trailers were developed. To improve the maneuverability of these vehicles the trailers are equipped with steerable axles. A prerequisite for such an automatic guidance system is the determination of the driven track of the vehicle. In contrast to autonomous vehicles the track of the vehicle only needs to be described relative to the current position. Common vehicle sensors such as incremental encoders, inertial measurement units and angle sensors are used. The intention of the paper is to design a fault-tolerant estimation algorithm with fault detection and isolation (FDI) for track estimation based on different estimation methods and a suitable selection of varying sensor sets. The algorithm is based on a kinematic truck-trailer model and different measurement variables, for example articulation angles, steering angles, wheel velocities or yaw rates of each vehicle element. Therefore the diagnosis of sensor faults is investigated and the design of a fault detection system is considered, using a model-based approach, with observer-based comparison of the available measurement data of the vehicle with the estimated sensor data, called residual generation.

A binary decision, either that something is going wrong or everything is fine is made by an analysis of the residuals. This knowledge can be represented in causal relation in form of rules to isolate the faulty sensor and determine the best estimation of the track. The use of a multiple estimator system for FDI with a bank of different observer and filter methods can clearly improved the accuracy of the state estimation.

For the various estimators a suitable selection of sensor sets has been made, which partially supply redundant or complementary measuring information. An observability analysis is

accomplished, where affect of the sensor sets to the state estimation can be shown. Simulation results derived from a validated dynamic model of the Fraunhofer experimental vehicle ELENA show that in case of sensor faults or losses the track estimation algorithm supplies clearly better results when using FDI techniques.

Session 2.2 Assistance Systems
Time: Wednesday, 14.09.2011
Location: Humboldt Building, Lecture Room 129
Chairman: C. Behn (D-Ilmenau)

9:00 a.m.	A. Baltrusaitis (LT-Kaunas)

Modelling of creativity and collaboration methodology for development the Manu future products and processes

Due to increasing international competition, the industrial sector and its development has a significant impact on the social and economic situation in industrial countries. Technological information and sources are constantly changing. Therefore, engineers must cooperate with knowledge creators. Analysis of products created by others, and cooperation results in both the creation of new ways of thinking and applications to enhance engineers' creativity. Manufacturers, consumers, authorities, and communities must cooperate, think creatively, and support manufacturing practices in order to improve the quality of manufacturing and design. Engineering activity may be very creative irrespective of the engineering branch. Creativity is crucial for organizations wishing to enter the future manufacturing market. Understanding of how their products will be used provides engineers with the perspective to think creatively. Future manufacturing products and processes will be highly dependent on newly-created knowledge, working methods and the newly-developed technologies used in the early stage of product or process construction. An interface of social and domain aspects facilitates the determination of creativity enhancing factors during the process of designing a product or a process. The process of designing an innovative product requires good understanding of constantly changing consumer needs and expectations. An integrated production process aimed to make assessment of consumer requirements more flexible, to implement new and more creative constructional changes, and to reduce the costs and time of designing and manufacturing new products. Moreover, the impact of constructional elements on production costs was assessed, and theoretical nonograms of typical constructional elements were created. After random selection of eight realistic elements, they were designed in a virtual environment, and after performing the calculation, the values obtained were marked in the above-mentioned nonograms, and compared to theoretical calculations.

9:20 a.m.	H. Hofmann (D-Aschersleben), M. Hofmann (USA-Cambridge)

Novel drive concept for the use in assistance systems

9:40 a.m.	D. Wittmann (D-Manching)

Development and evaluation of stereoscopic situation displays for air traffic Control

The present study investigates the suitability of stereoscopic 3D displays for Air Traffic Control (ATC) purposes. Two groups of participants, air traffic controllers and laypersons, were asked to judge various potential conflict situations involving two aircraft, using a specifically developed console work station that enables a comparative evaluation of different 3D visualisations and the current 2D display. The quality of judgements in combination with usabil-

ity and workload ratings is used as metrics to identify the most appropriate visualisation concept. For part of the scenarios, the conflict detection task was carried out with an additional secondary task. Considering exclusively the quality of judgement values laypersons generally achieve a higher performance when using 3D displays, whereas ATC controllers exhibit a constantly high performance with all visualisations. Particularly in scenarios that are difficult to assess and under secondary task conditions the laypersons seem to benefit from the 3D presentations, whereas the experts perform better with the 2D reference. From the quality of judgement values alone no preference is evident for a particular 3D concept. Taking into account the usability and workload ratings, however, the picture gains contour. Laypersons prefer the variant "3D with perpendicular" while experts are in favour of their familiar 2D variant, with the "3D with perpendicular" concept being their second choice. The results, however, are preliminary as the study is still ongoing.

10:00 a.m.	J. Costa, J. Teixeira, L. Silva, S. Teixeira (P-Minho)

Experimental Analysis of Particles flow inside the Volumatic® Spacer

Presently there are several studies regarding the performance of many pMDIs (or pressurized Metered-Dose Inhalers), more precisely spacers, with special emphasis on the study and analysis of the fluids using CFD (Computational Fluids Dynamics) software, on this specific case, Fluent™. The Volumatic® is the most commonly used spacer nowadays, and, therefore, the one that has been more studied. However, and spite all the simulations carried out with air and drug particles, there is no confirmation with an actual experimental testing procedure regarding the drug dynamics inside a particular spacer. Therefore, and to validate the simulated studies carried out before in this area, a mechanical system able to duplicate the respiratory system was designed and implemented so that the same conditions inputted to the simulation tools could be tested and compared. In order to collect the data for this analysis, the LDA (or Laser Doppler Anemometry) technique was used, which enables the measurement of the velocity of the particles through the center and some frontier regions of the studied spacer. As expected, it was possible to observe areas of recirculation, with a similar tendency of those obtained during simulation. The main difference relied on the absolute values of the velocity, which might be related with the lack of symmetry along the spacer and also probably due to the turbulent flow that probably exists inside the tube included in the mechanism used to simulate the respiratory system.

10:20 a.m. - 10:40 a.m. Coffee break

Chairman: A. Karguth (D-Ilmenau)

10:40 a.m.	M. Schäfer, C. Behn, T. Schmitz (D-Ilmenau)

Transversal Vibrations of Beams with Boundary Damping in the Context of Animal Vibrissae

Mice and rats use a sophisticated sensory system to acquire tactile information about their surroundings. Vibrissae, located in the mystacial pad, are either used passively to sense environmental forces (e.g., wind) or actively, when they rhythmically scan objects or surfaces. Some approaches to the biological paradigm vibrissa use rigid body systems in which a rod-like vibrissa is supported by a combination of spring and damping elements modeling the viscoelastic properties of the follicle-sinus-complex. However, these models can only offer limited information about the functionality of the biological sensory system, as they neglect its determining property: the inherent elasticity of the tactile hair. To increase the accuracy and the applicability of the gathered information, the vibrissa is modeled as an elastic beam in this paper. The classical differential equation (derived from the Euler-Bernoulli-equations) is applied to vibrissa beam models with varying supports using discrete and continuously distributed spring and damping elements. The eigenfrequency spectrum of such beams are being determined analytically and numerically, while varying the viscoelastic properties of the support.

11:00 a.m.	T. Schmitz, C. Behn (D-Ilmenau)

Analytical Investigations and Adaptive Control of Vibrissae-like Sensor Models with Finite DoF

Mice and rats use a sophisticated sensory system to acquire tactile information about their surroundings. Vibrissae, located in the mystacial pad, are either used passively to sense environmental forces, e.g., wind, or actively, when they are rhythmically moved to scan objects or surfaces. Inspired by this biological sensory system, three mechanical models with a rigid, rod-like vibrissa are developed based on findings in the literature. The models take into account the viscoelastic support of the vibrissa in the mystacial pad (follicle-sinus-complex and skin) on the one hand, and on the other hand they simulate the muscles (extrinsic and intrinsic) empowering the animals to whisk actively by using adaptive control algorithms. To model the range of movement of the biological vibrissa, the degree of freedom is gradually increased from 1 to 3 – enabling the examination of the support's influence on the sensitivity of the system. Numerical simulations with chosen perturbation forces show that specific control variables contain adequate information on the force to be identified.

11:20 a.m.	P. Loepelmann, C. Behn (D-Ilmenau)

Various adaptive Control Strategies applied to a bio-inspired Receptor Model

The motivation of this work is formed by the biologically inspired vibrissa sensory system. It is modeled as a spring-mass-damper oscillator with a spacial disturbance signal acting on the frame and an inner active element that generates a force acting on the mass. Both the

system parameters and the excitation signal are supposed to be unknown. The goal is to achieve a predefined movement of the mass, such as tracking a set point trajectory or stabilization. Thus, a controller is needed to act on the system using the control force as input in such a way that the desired behavior is generated. This is done by means of high-gain-stabilization. Like its biological paradigm, the receptor is in a permanent state of adaption. This means that recurring disturbances, such as wind acting on the vibrissa, are damped in order to achieve lambda-stabilization. To achieve this control goal and at the same time deal with unknown systems, adaptive controllers are introduced.

11:40 a.m.	M. Schweitzer, A. Karguth, Ch. Trommer (D-Ilmenau)

Remote rehabilitation assistance with the compliant robot arm BioRob

Within the scope of network based and individualized apartment and building service engineering, a standardized solution becomes more and more important for the multitude of integrable devices. Each of such services and devices came with a particular communication, protocol and analysis, requiring particular process reactions and parallel investments additional to further devices. The approach of the Smart-Home-Services project is to merge the communication of each single service to a standardized system. In a special application for this service system the compliant robot arm BioRob will be used for a remote rehabilitation assistance service. The new biologically inspired, light-weight and elastic robot arm offers a very high safety for patients in a similar way to a human arm. This paper shows the requirements and abilities of the compliant robot arm in rehabilitation assistance service applications which offer patients to practice relearning their own arm movements while their therapist controls and supervises this procedure by distance.

12:00 noon – 1:00 p.m. Lunch

Session 2.2 Assistance Systems
Time: Thursday, 15.09.2011
Location: Humboldt Building, Lecture Room 129
Chairman: K. Zimmermann (D-Ilmenau)

9:00 a.m.	A. Chigarev (BY-Minsk)

Automatic stabilization of translational motion of a microrobot

The analog motion control of a microrobot with feedback requires a more complicated structure due to the corresponding sensors, microprocessors and actuators. Application of the digital control system allows the use of a control algorithm, such as the autopilot, without feedback, which allows us to simplify the system. We consider the stabilization of the motion of the microrobot on a horizontal surface along the given motion trajectory. Minimization of the deviation angle of the robot's axis from the tangent to the motion trajectory is a criterion for quality control and can be implemented by the digital device with a hysteresis characteristic.

9:20 a.m.	L. Hartmann, M. Schulke, C. Behn (D-Ilmenau)

Worm-like Locomotion Systems: Development of Drives and selective anisotropic friction Structures

This paper is about the analysis, classification and valuation as well as the synthesis, development and construction of non-pedal, undulatory, peristaltic locomotion systems. An extensive literature research shows a broad spectrum of prototypes. Based on a functional structure of an earthworm segment these existing locomotion systems are analyzed with focus on the conversion of functional and structural relations of the earthworm (biological paradigm). The earthworm is able to affect the resistance against movement of each segment. In this paper we focus on the manipulation of the resistance against movement by bristles of adjustable pitch angle. Several principles to adjust the pitch angle of the bristles being in contact with the ground are developed accordingly to the constructive process of development. The developed principles belong to defined main groups. Finally a particular worm like locomotion system is introduced. The unusual feature of this new system is the realization of all sub-functions, i.e., the periodic drive and the alignment of the bristles, with only one central drive.

9:40 a.m.	V. Lysenko (BY-Minsk)

Novel mobile vibro-robot for locomotion through pipelines

The subject of our work is the creation of different designs of mobile robots for the movement through pipelines and similar technical systems. Using the transversal vibrations of an elastic bristle body, allows us to develop a new crawling vibro-robot. The motion is mainly realized by anisotropic friction forces. For the design process, we use the well-known construction principle of combination of alternative systems. It enables the transfer of structural characteristics (i.e. its kinematics) from one object to another, leading to new desirable characteristics or optimisations of existing technical objects. An analytical model of the motion of the bristles is presented.

10:00 a.m.	V. Minchenya, A. Chigarev (BY-Minsk), F. Becker, K. Zimmermann (D-Ilmenau)

Influence of the legs' geometry on the dynamics of a piezo-microrobot

The object of research of this work is a micro robot based on vibrating piezoelectric actuators. Micro robot's motion is realized by a vibratory drive (piezoelectric, asymmetrical vibrator, etc.). The geometry of the robot determines the frequency spectrum of its oscillations. Resonant excitation of the robot body leads to a transfer of the vibration energy to the limbs, which allows the transforming of the periodic motion into the forward one, at a certain synchronization of their oscillations. The main role in the transformation of these motions plays the geometry of the limbs, which consist of three links. The length of the links and the angles between the links affect significantly the nature of the transformation of the vibrations. There exist translational and rotational motions of the micro robot. Since the actuators of the limbs are realized in form of an elastic triangular or elliptical plate, we solve the problem through the finding the natural oscillations and the corresponding frequency spectrum.

10:20 - 10:40 Coffee break

Chairman: V. Lysenko (BY-Minsk)

10:40 a.m.	G. Kato, E. Pozo (PE-Lima)

Trajectory Generation Experimental Results of a Single Traction Ball Mobile Robot

In this study, the preliminary experimental results of a single traction ball mobile robot are presented. The robot was designed, constructed and tested. A simple control system was developed to control the moving distance of the robot. The mobility experiments have been documented for further investigations. The objective of the single traction ball robot is to move in any direction and be able to change it without making a twist. By the use of two perpendicular DC motors with rollers over a rubber ball, the robot is able to move in any direction by combining the spin of both actuators. A theoretical model of the system was developed to analyze the possibilities of controlling the exact movement of the robot by the voltage applied to the motors. Considering that the model has identical characteristics in both axis (X and Y) we can create a single model that will work for both and join them to create a full displacement system (plane XY). A number of tests were conducted to evaluated and characterize the performance of the mechanical and electronic control drive of the robot. The Straight line movement experiments were designed to evaluate the performance of the displacement of the robot in a single direction controlled by a single motor at a time. The Sideway movement experiments were designed to evaluate the performance of the displacement of the robot in a single direction controlled by both. The Circular movement experiments were designed to evaluate the performance of the displacement of the robot in a sequence of multiple directions, which is the highest requirement for the robot. The single traction ball robot was able to move in a series of different direction and distance movements according to its programming; however, it is also shown a low precision in distances, no symmetry in displacement and a no displacement case (SW) due to mechanical errors and assembly problems. Since the electronic control board design is sufficient to control the motors used in the mechanical drive of the single traction ball, but the mechanical drive developed is not sufficient to realize an accurate study of the omnidireccional displacement system due to assembly and design problems; it is possible to develop a new one to continue the studies.

11:00 a.m.	J. Popp, I. Zeidis, K. Zimmermann (D-Ilmenau), V. A. Naletova, V. A. Turkov (RUS-Moskau)

A theoretical and experimental approach to the investigation of ferrofluid based locomotion systems

11:20 a.m.	F. Becker, K. Zimmermann, I. Zeidis (D-Ilmenau), V. Minchenya (BY-Minsk)

Modeling and Dynamical Simulation of Vibration-driven Robots

In this paper piezo-driven micro robots are introduced for 2-dimensional locomotion on a flat solid surface. To find important locomotion effects an experimental setup using a scanning electron microscope is presented. The results are given and the principles of motion are described. The working principle of this type of robots deploys forced vibrations of continua. The non-classical legs are excited by the actuator with frequencies in range of 1 – 100 kHz, which leads to complex trajectories at the endpoints of the legs. The behavior of the actuator is studied in detail using analytical models based on Kirchhoff hypothesis of plates and laminates, as well as computational models. The results are compared with experimental investigations.

11:40 a.m.	K. Zimmermann, I. Zeidis (D-Ilmenau), N. Bolotnik (RUS-Moskau), S. Yatsun (RUS-Kursk)

Vibration Driven Robots

The design of mobile robots that can move without wheels or legs is an actual engineering and technological problem. Vibration driven robots are locomotion systems that realize a locomotion in a resistive environment without specific propelling devices (wheels, legs, caterpillars, screws) due to oscillatory or undulatory relative motion of their components, part or all of which interact with the environment. Self-propelling mechanisms that consist of a body that has contact with a rough surface and internal masses are considered. Asymmetry in friction that is necessary for the robot to move can be provided in several ways. The robot is equipped with specific contact devises that provide anisotropy for the coefficient of friction, i.e., the coefficient of friction depends on the direction of motion. For example, the contact surface of the robot can be covered with needles. The asymmetry can be provided for isotropic friction by changing the normal pressure of the robot on supporting surface. In this paper we present some basic mathematical models and a prototype of such vibration driven robots.

12:00 noon – 1:30 p.m. Lunch

S. Linß, St. Griebel, T. Kikova, L. Zentner (D-Ilmenau)

Pneumatically driven compliant structures based on the multi-arc principle for the use in adaptive support devices

Adaptive support devices for bedded patients must allow a special relief for pressure reduction of compressed skin areas but also a suitable stimulation regarding the prevention and treatment of bedsores. Pneumatically driven compliant mechanisms offer great potential to influence the deformation behavior by geometrical design and/or material choice.
This contribution deals with the FEM-based investigation and development of a compliant fluid actuator realizing a large stroke. Therefore, a multi-arched structure consisting of silicone is designed, developed and tested with an experimental setup. Moreover, the advantages of an additional position measurement based on electrically conductive foams, a mechanical adaptive patient contact and an adjustable stiffness of the flexible mechatronic demonstrator are described.

Topic 3:

Systems Technology

Session 3.1.1 Material Properties, Manufacturing, Assembly

Time: Monday, 12.09.2011
Location: Humboldt Building, Lecture Room 211/212
Chairman: J.-P. Bergmann (D-Ilmenau)

10:20 a.m.	U. Kletzin, R. Lux, P. Beyer (D-Ilmenau)

Optimized Heat Treatment in Wire and Spring Production

Current research reveals that the heat treatment of wire and the heat treatment to harden wire and to temper springs must be taken in conjunction with each other in order to improve strength and shaping properties of oil-hardened spring steel wire. An experimental hardening and tempering plant developed at Ilmenau University of Technology in the laboratory of the "Wire and Spring" research group has been used to carry out experiments on many variations of all heat treatment parameters. This paper is a survey of the experiments using certain of the results as an example of how it will be possible to make stronger springs in future if the wire and spring industry cooperate, also thereby consuming less energy.

10:40 a.m.	M. Weiß, J. Steigenberger, V. Geinitz, P. Beyer (D-Ilmenau)

Extreme Bending of Spring Steel Wire - Theory and Experiment

The paper is a report on recent experimental investigations of spring-steel wires. Spring-steel is a high quality product of the wire industry with outstanding mechanical properties which should ensure that components such as compression springs with smallest mass produce high spring forces. The experimental set-up is a three-point bending test rig. Aim of the experiments was (1) to find the limit of extreme elastic bending of wires – the spring bending limit, and (2) to determine the elasticity modulus of spring-steel via bending thereby using test objects having a pre-curvature. For a quantitative interpretation of the experimental results a suitable mathematical framework is inevitable. To this end an non-linear theory for bending elastic rods is presented. It goes a bit beyond the common mathematical description since different kinds of bearings are considered, and the rods used for the determination of the E-modulus are allowed to be pre-curved. The quantitative mathematical results are gained numerically and afterwards partly presented by handy approximate formulas. Generally, the theoretical considerations are given in a universally utilizable form (use of normalized dimensionless quantities). The experimental set-up and the run of experiments are explained and examples of relevant measuring results are presented.

11:00 a.m.	M. Schlüter, I. Stodtko (D-Ilmenau)

Changeability Training for Employees in Manual Assembly

Changeability is a success factor for companies as they are facing increasing market dynamics such as shorter product life cycles, fluctuating demands and higher product complexity. For this reason a training concept to improve changeability of employees in manual assembly has been developed. Focus of this training is the routines that are used during manual assembly processes. The elements within the training concept are derived from methods used for changeability training in gymnastics. The plausibility of this transfer from gymnastics to manual assembly has been shown by a detailed comparison of the two domains.

To demonstrate the effectiveness of the changeability training an assembly simulation has been applied. In order to easily use the training for companies, it is build up in a scalable way so that it can be adapted without difficulty to company specific needs and with respect to the conditions of employees and the organisation.

11:20 a.m.	Ch. Lauter, M. Frantz, Th. Tröster (D-Paderborn)

Advanced Manufacturing Technologies for Automotive Structures in Multi-Material Design Consisting of High-Strength Steels and CFRP

This paper will show basic technological investigations in the field of prepreg-press-technology to manufacture multi-material or hybrid structures for automotive applications. After giving an overview of the process, research results regarding process and forming parameters as well as process control and cycle times will be discussed. Additional results for crash tests, e. g. of double-Z-profiles, demonstrate the crashworthiness of this new class of materials. Finally, detailed concepts for high-volume processing of structural automotive components with multi-material systems will be discussed. With expected cycle times of 2 to 5 minutes the developed approaches for manufacturing local reinforced structures are possibilities to solve the challenges of high-volume manufacturing in the field of CFRP.

11:40 a.m.	A. Boaron, W. L. Weingaertner (BR-Florianópolis)

An Application of the Acoustic Emission for Monitoring the Topography of Grinding Wheels

A quick-test method for the determination of the topographic characteristics of a CBN grinding wheel is proposed based on acoustic emission technology. To implement the method, an acoustic emission (AE) monitoring system was integrated into a 3 axis CNC grinding machine in order to detect a precise reference position on the grinding wheel's periphery. This system permits to recognize interferences between the grinding wheel and dressing tool in a range of a few micrometers. The acquired AERMS signals from these interferences are used in order to establish an on-line map of the grinding wheel periphery, indicating the active cutting edges up to a depth of interference of the dressing single point diamond and the grinding wheel. The obtained map of the grinding wheel is compared to a previous developed model as a manner to validate the results.

Index Terms – External Grinding, Grinding Tool Mapping, Monitoring Systems, Acoustic Emission.

12:00 noon – 1:00 p.m. Lunch

Poster Session 3.1.1 Material Properties, Manufacturing, Assembly
Time: Tuesday, 13.09.201, 12:00 noon - 1:30 p.m.
Location: Foyer Humboldt Building

A. Al Khateeb (D-Ilmenau)

Investigation of Economic Alternatives for the Configuration of Flow Production Systems

In order to achieve a given output of a product in the planned period, the structure of the flow production system must be considered and selected. The structure alternatives differ from each other with the numbers of identical parallel flow lines, station numbers in each line and the cycle times. In the department for industrial engineering at Ilmenau University of Technology, a strategy for optimization of identical flow lines was developed so that the parallel buffers were combined with each other. The previous investigations of this strategy defined many logistical advantages. For this reason it is useful to organize and carry out further investigations which may lead to the use of this strategy in the industry.
Based on an example, alternatives for planning and combination of identical flow lines are studied and presented. Furthermore, this paper offers two models for the realization of the tested flow system.

Y. Litvinau, S. Karpovich (BY-Minsk)

On-the-Fly Reconfigurable Parallel Manipulators

The synthesis and prototyping of parallel manipulators capable of on-the-fly self-reconfiguration is considered in the paper. The on-the-fly self-reconfigurable parallel manipulators are capable of changing their kinematic structure autonomously, without any external interference. The multi-degree-of-freedom systems constructed on the basis of such parallel manipulators are among the most perspective solutions for spatial movements implementation. Rapid synthesis and prototyping of the on-the-fly self-reconfigurable parallel manipulators is one of the issues in the sphere of robotics. Therefore the paper examines the development of the parallel manipulators capable of on-the-fly self-reconfiguration. The design methodology is presented. Using the modular components approach and mobility analysis kinematic chains configurations and constraints are identified.

Session 3.1.2 Design Methods and Processes

Time: Tuesday, 13.09.2011
Location: Humboldt Building, Lecture Room 211/212
Chairman: Ch. Weber (D-Ilmenau)

9:00 a.m.	M. Braunschweig, M. Weiß, K. Liebermann (D-Ilmenau)

Supply of Measurement Results of Spring Wire Tests on the Internet
Within the scope of a research project, extensive measurements for the determination of spring wire properties relevant for operation and production were carried out. To provide the properties and characteristics accessibly for companies involved in the project, a SQL-database to store the measurement results was developed. The User-Interface is a Website, no special software has to be installed. The paper presents the new software technologies which allow it to develop very well structured modules with high flexibility for the Website. This is necessary because the companies use the measuring data entirely different. In addition in the future new tests are developed and the database structure is dynamic.
The following software technologies should be discussed: ASP.NET MVC 3 Framework from Microsoft, JavaScript and Ajax, LINQ and Data Visualization with Charts. The goal is to create the highest quality, most robust, simple and maintainable code possible.

9:20 a.m.	C. Schilling, S. Köhring, H. Witte (D-Ilmenau), M. Schrödner (D-Rudolstadt), A. Huba, I. Muka (H-Budapest)

Results of Modeling the Mechanical Behavior of an Ionic Polymer-Metal-Composite for Assembling as Actuation Systems
The department of Biomechatronics (IMN MacroNano®) currently is working on the implementation of biomimetic principles into actuatoric polymer elements. Due to proton permeability the material Nafion™ is of high interest in several fields of technology. If Nafion™ is covered with a metallic layer on both sides and a voltage is applied, an actuatoric effect is the result. In the case of a square shaped foil, spherical bending can be observed. The first attempt in design of motion systems is the transformation of the bending into linear motions. Several applications seem possible if the actuatoric substrate IPMC will be maintainable in different environments and capable for precise control of the motion parameters by electrical signals.

9:40 a.m.	S. Linß, T. Erbe, L. Zentner (D-Ilmenau)

Design and Simplified Manufacturing of Large-Deflective Flexure Hinges Based on Polynomial Contours
Material coherent flexure hinges with lumped compliance allow a specific geometrical design of monolithic compliant mechanisms and their deformation behavior. This contribution deals with the model-based design and simplified manufacturing of prismatic flexure hinges with symmetric polynomial notch contours to increase the motion range. Therefore the hinge geometry is described examplarily by polynomial functions as well as simplified notch contours based on radii. FEM simulations are used to verify the determined polynomials and approximated contours regarding a minimal ratio of maximum stress to deflection depending on the polynomial order.

10:00 a.m.	F. Nehuis (D-Braunschweig)

Application of a Sales-Tool for Optimized Quote Preparation in Small and Medium-Sized Companies

Global competition and the high cost of production in particular in Central Europe are forcing companies to develop innovative products in shorter cycles and to increase the quality of products. To meet the expectations of customers is a key success factor. This paper describes an optimized methodology for fast, high-quality design of individual customized products. For the modeling of product knowledge are presented here methods that are being tested in a benchmark company. Furthermore, software is presented, which allows small and medium-sized companies, to configure products for small batch and single production. The aim is to enable these companies to respond to individual customer inquiries in less time with suitable offers.

10:20 a.m. - 10:40 a.m. Coffee break

10:40 a.m.	M. Vielhaber (D-Saarbrücken)

Design to Knowledge - a Root Design Principle

"Design to" and "design for" principles are used to support and improve engineering processes with regards to a specific target area. This paper introduces design to knowledge as an operationalization approach for the knowledge oriented engineering paradigm, which bases on the philosophy of lean product development and sets knowledge aside to the product as a second deliverable of the design process. Special focus is put on the method of knowledge stream analysis as a means to systematically identify knowledge oriented gaps and value losses along the design process as well as respective improvement potentials. While being primarily meant as an analysis and synthesis tool to improve real design processes, this method is in this paper exemplarily applied on the VDI 2221 guideline as an example for contemporary design methodologies. Significant knowledge-oriented improvement potentials to this methodology are identified. Finally, it will be argued that, through a consistent application of design to knowledge, design processes could be improved in a way that other design to and design for principles are inherently facilitated, or even automatically fulfilled.

11:00 a.m.	P. Hehenberger, K. Zemann (A-Linz), K. Kittel, S. Vajna (D-Magdeburg)

Autogenetic Modelling and Optimization of Reduced System Models

Mechatronic systems are multidisciplinary products and therefore the knowledge required for developing such products/systems is extensive. For the optimization of a mechatronic system, it is necessary to build an overall system model. One important approach is to use reduced models that may be derived from more detailed models. The determination of some important design parameters is very helpful for using a Natural Optimisation Algorithm (NOA). The approach of optimization using reduced system models is presented by analyzing a drive train of a rolling mill.

11:20 a.m.	Ph. Klein, M. Weyrich, M. Laurowski, Y. Wang (D-Siegen)

A Function-Oriented Approach for a Mechatronic Modularization of a Sensor-Guided Manufacturing System

Nowadays, the development of special machines still depends a lot on the experience and knowledge about mechanic design and construction. This paper presents an innovative approach for reusing mechatronic modules that are assigned to so called solution neutral functions. This way, the developer is able to conceive a modularized blueprint based on a description of the function of the special machine. Thereafter, the developers have to select matching modules from a catalog. An important prerequisite is to modularize mechatronic system in such a way, that they can be resued in various machines. Therefore, machine systems are modularised by an extended Axiomatic Design. The resulting modules have to be assigned to solution-neutral functional descriptions and integrated into a database. In the present paper both, the approach for the modularization and to the development, will be presented and illustrated by examples.

11:40 a.m.	E. Seabra, L. Ferreira da Silva, J. Machado (P-Guimarães)

Design and Development of a Feeding Aid Device to Assist People with Deficiency

The present work intends to design new devices of aid to the feeding for individuals with deficiency. Like this, along this paper they are referred the most relevant pathologies, which affect the autonomy of the patient's feeding, as well as some existent devices in the market. Based on the characteristics of these devices, this research was performed with the main objective of finding the most appropriate actuation system. Furthermore, it was made the analysis and discussion of the performance specifications, essential stage in the design process of the feeding aid device for this to assure all the demanded requirements. Afterward, they are pointed some possible solutions, in the sense of creating more and better on behalf of the patient's need. Finally, for the solution selected, it was being later developed a model, in the advanced software Working Model for the simulation of the mechanical system of aid feeding.

12:00 noon – 1:30 p.m. Lunch

Session 3.1.3 Machine Elements and Systems
Time: Tuesday, 13.09.2011
Location: Humboldt Building, Lecture Room 211/212
Chairman: U. Kletzin (D-Ilmenau)

1:30 p.m.	O. Calonius, P. Kiviluoma, P. Kuosmanen (FIN-Helsinki)

Large-Scale Test Rig for Assessment of Characteristics of Flat Air Bearings Running against a Rotating Counter-Face

Air bearing technology could provide a competitive alternative to conventional bearings if high enough load carrying capacity as well as tolerance for low surface quality could be obtained and combined with the low friction of the air bearings. Aerostatic bearings are typically characterized by load capacity, stiffness and air consumption. In this paper, a test rig for studying these operating characteristics of air bearings is presented. In the test rig it is possible to have circular thrust bearings running against a relatively fast moving circular counter surface. Two types of bearing units were studied: a traditional, orifice compensated air bearing and a porous material air bearing.

A large-size lathe was chosen as a basis for the test rig because of the rigid structure and precise guide ways. The speed of rotation of the counter surface can be controlled in a range from 5 rpm to 500 rpm and the maximum diameter of the counter-face is 1000 mm. The loading force is adjusted by hand screw. A force transducer, attached to the bearing support, measures the bearing load. Gap height and bearing alignment are measured using three displacement transducers directly attached to the bearing. First test disk was a used roll end, 1000 mm in diameter, and had grooves, indentations and bearing metal traces on its surface. Second test disk, 400 mm in diameter, manufactured for test purposes only, was finished by surface grinding. There were two categories of tests. Tests with a stationary counter surface to determine bearing stiffness and air consumption and tests with a rotating counter surface with axial run-out.

The static measurements show that there is a difference between the behaviors of the two bearing types. Porous bearing operates with smaller air gap and its stiffness rises rapidly as the air gap gets smaller. Orifice type bearing allows higher air gap on its nominal operating range. The larger air consumption in the orifice type bearing corresponds with the larger air gap. The test rig is a promising platform for studies involving either large-size counter surfaces, the need to change counter surfaces or the development of new large-size air bearing solutions for industrial purposes. The test rig can also be used in validating computational bearing models.

1:50 p.m.	J. Chigareva, V. Minchenya (BY-Minsk)

Damage mechanism in the Cermet fuel rod shell undergoing a rapid cooling

Destruction of the fuel rod shells in nuclear reactors lead to hazardous emergency situations. There can be various causes and scenarios of such accidents. One of the reasons can be an overcooling of the circulating medium surrounding the fuel rod. We consider a problem of calculation of the stress-strain condition in the cylindrical and spherical type fuel rod shells undergoing a rapid cooling of the outer surface. The outer surface of the shell is cooled down to a reference value of 0 °C. We analyse the resulting process of development of the plastic deformation zone in the material of the shell. The transient problem is solved for the heat transfer calculation. The stress-strain condition is calculated using a quasi-stationary approach in which the wave effects in the material are assumed as negligible.

2:10 p.m.	U. Kletzin, R. Reich (D-Ilmenau)

Fatigue Damage Parameter and their Use in Estimating Lifetime of Helical Compression Springs

The following essay deals with the usability of damage parameters with regard to helical compression springs. Different damage parameters were examined. Of these parameters the usability for helical compressive springs distinguishes decisively. The new PRKK fatigue parameter will make possible significantly better comparability between dynamic fatigue tests on helical compression springs of different mean stress. On the basis of these the design of helical compression springs under cyclical loads can take place with considerably improved lifetime prediction.

2:30 p.m.	S. Bobrowski, M. Döring, W. Schinköthe, U. Jensen (D-Stuttgart)

Reliability Prediction using the Cox Proportional Hazards Model

Currently, for a variety of systems and components, sufficient failure behaviour data are not available. This especially concerns failure data of many mechatronic, electromechanical and also mechanical components of machines and devices. Endurance tests at customer-specific operating conditions provide manufacturers with specific failure time data. In the end, they give information about the reliability and lifetime of products for a specific application. Endurance tests, however, are time-consuming and expensive. Performing tests, it is impossible to cover all of the imaginable combinations of applied load profiles and impact parameters. Additionally, significant statistical information also requires adequate test lot sizes. Furthermore, findings gained through experiments are valid only for the applied test conditions and loads respectively. On the other hand, developers require as early as possible meaningful key figures characterizing the applied components to determine the overall reliability of the device or machine. Often, modified components using the same technology basis are applied using other load profiles, so that available test data can not be used without further steps. Alternatively, one can try to derive sufficiently precise predictions for newly developed components or new application environments from a variety of existing data sets from endurance tests of similar components and other load cases. To this end, well-known regression models of survival analysis have been developed further, adopted

and tested for engineering applications. The final objective of this entire research project is, to develop prediction tools for the use of existing failure data to statistically predict the failure behaviour for values of the covariates that were not directly tested in different stages of development and points in the life cycle. These tools serve to provide a high-quality prediction of reliability for mechatronic or other components. To illustrate the transferability to applications for reliability prediction, test data of DC motors from in-house experiments and simulated data sets are adapted to a Cox proportional hazards model.

2:50 – 3:10 p.m. Coffee break

3:10 p.m.	V. Geinitz, M. Weiß, U. Kletzin, P. Beyer (D-Ilmenau)

Relaxation of Helical Springs and Spring Steel Wires

Relaxation is the term used for the degree to which a spring of constant length loses its force over time. Diagrams of the relaxation that takes place in cold-shaped helical compression springs are given in the European standard EN 13906-1. The questions to ask about it are how it comes about, which properties of the material are important for relaxation and, then, which steps in the manufacturing steps of the spring and/or which parameters have what effect on the force lost by relaxation of the spring. Answering these questions will mean it should be possible to improve spring quality systematically by reducing the loss of force from relaxation. A necessary procedure is to establish the relaxation behaviour of the wire used for the spring and then compare it with the relaxation behaviour of the spring made from the wire. The investigations of the wire provide knowledge of relaxation affected only by the material properties and the conditions in which the relaxation takes place. The relaxation of the finished springs will, of course, also be influenced by the process stages to which the wire is submitted during spring manufacture.
The paper presents the idea, the experimental setup and procedure as well as the results of relaxation tests with helical compression springs and spring steel wires.

3:30 p.m.	U. Kletzin, V. Gevorgyan (D-Ilmenau)

Contact Pressure and Wear on Helical Compression Springs

Among the factors determining the life and liability of mechanical parts in machinery, apparatus and plant is safe functioning of the spring components. The demands placed on helical compression springs by friction will cause wear and can cause failure of the element and therefore of the whole component. The aim of the present paper is to shed light on the influence of contact pressure on the wear and tear that arises between the end coil and the spring seat or between the end coil and the transition coil by using pressure measurements and FEM calculations; also to shed light on the influence of the surface roughness on the wear by means of tribological tests on a selection of surface roughness types for specially shot peened wires, all in order to improve the function and lifetime of these commonly used parts and the components into which they are installed.

3:50 p.m.	Ch. Wehmann, F. Rieg (D-Bayreuth)

Development and Comparison of High Order Toroidal Finite Elements for Calculating Disc Springs

The present paper deals with the development and the application of toroidal finite ele-

ments. These finite elements belong to the class of curvilinear elements and therefore a special element formulation is required. This means to express stress, strain and displacement in curvilinear coordinates. Here, an 8-node quadrilateral element is developed, which is described by an isoparametric interpolation. The development of the governing equations is one main topic of this contribution. First of all the equilibrium equations for nonlinear elasticity are expressed in cylinder coordinates. This includes the development of Lagrangian strain coordinates related to the physical cylinder coordinate basis. Concerning the material behavior, the generalized Hooke's law is applied, which is valid for large displacements and small strains. In addition, the discretization is developed by accounting symmetry properties. The resulting nonlinear toroidal element is implemented in the finite element system Z88. Having implemented the finite element code, disc springs with different heights are calculated. Two different solvers are applied, one is based on a Newton-Raphson-procedure and the other is based on a procedure of Riks. The Newton-Raphson-solver is controlled by load, whereas the solver based on Riks procedure is controlled by a composition of load and displacement. This is why the latter has the advantage of being able to calculate disc springs with negative spring rates. Another main topic of the present paper is to evaluate the quality and efficiency of these elements with respect to the calculation of disc springs. Beside low computing times, toroidal elements have another great advantage for calculating machine elements with rotational symmetry: results like stress distributions can be visualized directly to the cross section. In the present paper calculations with toroidal elements are checked against experimental data, which consists of load-deflection-curves. A special experimental setup ensures to gain data up to large displacements. This helps to evaluate the quality of Riks procedure. In addition, the effects of friction and differences to the exact rectangular cross section are considered.

End of Lecture Session

O. Linins, D. Rags, N. Mozga (LV-Riga)

Calculation of Wear with Application of Stray Fields to Roughness Evaluation of Friction Surfaces

The purpose of the given work – a theoretical and experimental signature analysis of details of wear process in sliding couplers on the basis of the probability approach, which allows to consider process of wear by the account of stray character of a microcontour of surfaces affected by wear. Let's consider process of mechanical interaction of such surfaces of wear. In bands of contact of irregularities there is a deformation of a surface stratum of a material. The part of microroughness is deformed plastically and the part is elastic. After some number of effects at sliding of one detail concerning another there is separating a material as a particle of a wear. For exposition of the given process we shall use the probability approach permitting to consider process of wear as casual.

A. Bakhshyan, A. Pogosian (ARM-Yerevan)

Optimization of Brake Device Operating Characteristics in Anti-Lock Braking System

The brake device characteristics optimization is carried out. Deceleration, brake torque and braking distance optimal values are determined by means of the criterion functions depending on traction conditions of wheel with road and wheel slip coefficient. Brake device characteristics optimization is carried out by Gauss method which is called sections or successive descent method as well. The changing of deceleration, brake torque and braking distance values depending upon wheel slip coefficient relatively to road, automobile suspension stiffness and traction coefficient of wheel with road is considered, as these parameters essentially impact on operating characteristics of brake device.

Session 3.2 Sustainable Mobility
Time: Wednesday, 14.09.2011
Location: Humboldt Building, Humboldt Lecture Hall
Chairman: M. Koch (D-Ilmenau)

9:00 a.m.	K. Hiltmann, H.-H. Hartan (D-Coburg), W. Heubner (D-Ebern)

Identification and Realization of Innovation Potentials at a Drum Brake Using WOIS and TRIZ Methods

Drum brakes have been vehicle components for over 100 years and can be regarded as technically mature. They still possess certain characteristic weak points one of which is braking noise. For the purpose of functional modernization of this kind of brakes, innovative approaches have been investigated. A general directional search has been performed using elements of WOIS method after Linde. This method uses a series of different viewpoints and standardized criteria which a product is explored with. A considerable number of improvement notions have been found with this technique, out of which the challenge of noise reduction was selected. We have addressed this subject using TRIZ / TIPS method. It originated in the 1950ies in that-time Soviet Union and has been known in the Western World for some 20 years. The method's most common feature is a collection of technical guidelines for problem solving but it contains numerous other tools. One of those, the so-called Problem Formulation, has been used to set up a functional model of the brake noise problem. The model consists of cause-and-effect chains which can be traced and varied to achieve desired and to prevent undesired effects in a system. In this way, we could identify several approaches to diminish noise either by suppressing its origins or by avoiding its propagation. Some solutions are sketched here whereas practical tests are still being conducted.

9:20 a.m.	R. Horn (D-Ilmenau)

Characterization of particulate emissions of vehicle wheel brakes

The more and more restrictive environmental legislation requires a consideration of emitters beyond traditional combustion engine. At this, the particulate emissions of the brake play a crucial role. A future reduction will be possible only under consideration of the particles from the friction zone between brake disc and pads. Target is the characterization of these emissions by developing methods for analyses of expansion and agglom-eration. This will be the basis for a future development of measures to reduce emissions. Firstly, physical analyses were made for characterization. Therefore latest measuring technologies were used, such as scanning electron microscopy and laser light scattering systems. Methods were developed and imple-mented for sample preparation and study of influence parameters at an air-conditioned brake and chassis test bench. Hence the brake particles were profound analyzed. This resulted in boundary conditions for subsequent researches. Measure of particle loaded flow could be executed with the Particle Image Velocimetry. Furthermore the brake was simulated for the analyses of not measurable properties with computational fluid dynamics and validated with the above mentioned optical measuring system. Novelty value: Till today a holistic visualization of brake emissions, which combines analyses of particle loaded flow with physical examinations, couldn't be found in published papers yet.

9:40 a.m.	S. Beyersdorfer, S. Wagner, St. Zipser (D-Dresden)

Obstacle avoidance for multi-axle steered multi-body vehicles

During the last years commercial vehicles tend to become longer in order to increase carrying capacity and efficiency. But one of the main drawbacks of large heavy load vehicles is still the limited manoeuvrability. To overcome this disadvantage at least partially, these vehicles where designed of multiple bodies equipped with multiple steering axles. At first they where actuated by a steering linkage, approximately following the law of Ackermann. Recently the availability of electronically steerable axles is increasing, even for heavy vehicles. Currently such axles are already standard in modern agricultural machinery like tractors or combine harvesters or heavy load vehicles for wind power stations etc. With this technique, it is possible to realise more flexible and powerful steering strategies than with the classical mechanical approach, improving the stability as well as the manoeuvrability.
This paper discusses the novel idea of planning individual paths for every steering axle for the special task of successfully leading a multi-axle steered articulated vehicle through a narrow environment containing obstacles. Thus, the full potential of multi-steered axles is tapped in combination with collision avoidance. On the assumption that the vehicle moves very slowly, stability is not a critical question in this context. Path planning algorithms, known from robotics, are used to calculate the paths of the steering axles. The article explains the development of a path planning algorithm for multi-axle steered multi-body vehicles using the example of an articulated truck with two steering axles. The presented path planning algorithm is based on the well known A*-Algorithm. This algorithm is modified to consider the additional degree of freedom and plan individual paths for each steering axle. Simulations show, that multi-axle steering in combination with path planning can improve collision free large heavy load vehicle manoeuvrability. The algorithm allows a prediction whether a difficult scenario is passable or not. Furthermore, the calculated paths can be used to assist the driver. The presented algorithm is built in a modular manner, so that it is easy to extend it to other vehicle configurations (more steering axles, more pivot points, etc.).

10:00 a.m.	J. Schroeter (D-Karlsruhe)

Enhanced Approach for Computation of Vehicle Operation Strategies based on a self-learning Algorithm

The modern day automotive industry has reacted to the most recent concerns regarding CO2-emissions and the dwindling of global oil reserves by increasing their research and development efforts in fuel efficiency and emission reduction measures. An in-depth analysis reveals that success is not only dependable on the mere optimization of the vehicles components. It is also of utmost importance to take the drivers behavior and the effects it has on the performance of the vehicle into consideration. For this reason, modern day systems have been developed to assist the driver towards achieving higher efficiency even without dramatically changing the vehicles components.One possibility is the use of artificial intelligence in order to compute optimal trajectories and take the decision making over from the driver. Algorithms that scan through the entire space of possible solutions, so-called “full backup” optimization algorithms, present a solution for the prediction of the optimal operating points. The main disadvantage of their implementation lies within huge computational effort related to the necessity of scanning potentially immense spaces of

solutions. The paper discusses the potential of "sample back-up"-algorithms, e.g. Reinforcement Learning (RL), in order to cover computation effort problems without compromising the quality of the computed solution.

10:20 a.m. - 10:40 a.m. Coffee break

10:40 a.m. | S. Falke, H. Krömker (D-Ilmenau)

Predictive diagnosis of electric motors in automotive drives (PräDEM) – A user centered design approach

German Federal Government called for one million electric cars to be on German roads by 2020. To ensure driving safety, reliability in everyday life, and well-being of the driver the car should continuously monitor the electric motor, detect malfunction at an early stage, and warn the driver in an appropriate way. This paper focuses on user-centered design of ergonomically high-quality human-machine interfaces for predictive diagnosis of electrical motors in automotive drives as part of the overall project PräDEM. Therefore, a user-centered design approach is introduced and exemplarily shown for the role of drivers of electric cars. According to predictive diagnosis we demonstrate methods for specifying the context of use, deriving requirements, producing design solutions and evaluating those, involving potential users from the beginning of the development process.

11:00 a.m. | W. Waidmann (D-Aalen)

CFD Investigation of the injection and Combustion Process in a Diesel Engine

This paper describes the simulation of in-cylinder diesel injection and combustion. The numerical investigations were carried out on the basis of a Deutz 2014 heavy duty common rail diesel engine (2100 rpm, 232 PS, rail pressure 1600 bar, compression pressure 140 bar). A discrete phase model has been used for spray simulation. A primary break-up model and two secondary spray break-up mechanisms, the Kelvin-Helmholtz theory and Rayleigh-Taylor instabilities have been investigated. Droplet evaporation, droplet collision and the influence of droplet shape on drag has been accounted for. To verify the spray simulation, droplet diameters and velocity distributions have been compared with experimental data from a Phase Doppler Anemometry (PDA) measurement in a model chamber. The combustion is calculated with available models in Fluent, the Eddy-Dissipation Model (EDM), where the turbulent mixing is the time limiting process, the Eddy-Dissipation Concept model (EDC) and the Flamelet Model which both take account for kinetic effects. The Common-Rail Diesel injection results in spray atomization with very small mean droplet diameters. This guarantees effective evaporation of the fuel and enhanced mixing of the reactants. Multi-dimensional simulation of these processes is still an issue. The spray models currently available in the literature will not work without adjustment of constants and fitting parameters based on detailed measurements. However simulation of combustion and pollutant chemistry is not possible without correctly predicting the spray. The combustion is calculated with widely applied models available for turbulent non premixed combustion. The thermal loss due to the heat transfere through the cylinder head and the cylinder wall and the pressure loss through the piston rings were taken into account. The computational domain extends from the fresh air inlet duct, which operate as a vortex generator, the inlet valves to the moving piston.

12:00 noon – 1:00 p.m. Lunch

T. Gutjahr (D-Stuttgart)

Dynamic engine behavior identification for the use in model-based ECU calibration

The calibration of electronic control units (ECU) is one of the major parts within power train development. In order to accomplish project targets such as fuel consumption, emission limits or driving comfort, proper calibration with acceptable expenditure of time and costs is indispensable. Therefore, model-based ECU calibration is seen as one major solution by the simulation of relevant engine or vehicle behavior in terms of plant models, so that the main calibration task, the parameter optimization, can be done virtually. An additional benefit of this approach is the significantly reduced demand for prototypes and test bench runs. Nevertheless, current tools mostly provide only solutions to model the engine behavior in stationary operating points and do not consider time-dependent effects. This is yet insufficient for simulations of dynamic processes, e.g. engine emissions. For instance, up to 80% of the Diesel engine emissions are caused by dynamic effects. Concerning this issue, we introduce a regression framework consisting of a NARX (non-linear auto-regression with exogenous inputs) model structure for the consideration of the system time-dependencies and a data-based regression algorithm, the Gaussian Process for Regression, for identifying the latent input-output relationship. With the application of the Gaussian Process we are faced with its drawback of a high computational demand at tasks with a high input dimensionality ($D >> 100$) or a large training data set size ($N >> 1000$). To speed up the modeling framework we make use of a sparse GP approximation, the Subset of Regressors GP, and reduce the number of dimensions within the NARX structure, based on the theory of feature extraction. Thus, one major issue of this paper is also the comparison of recent approaches from linear feature extraction for our purposes. Finally, for the validation of our proposed approach we applied it to a real world example, the identification of a charge-air intercooler, of our cooperation partner, the Robert Bosch GmbH.

Social Events

Welcome Reception

Monday, 12.09.11, 3:30 p.m. – 7:00 p.m.

All lecturers, participants, guests and companies are kindly welcome to the Reception.

Weather permitting, the welcome reception will be given on the square in front of the Humboldt Building. Otherwise, our guests are kindly asked to go inside.

The Reception will be held immediately after the Opening Ceremony.

Enjoy yourselves!

Music provided by: Combo Second Unit Jazz

Social Events

Academic Gala Concert

Tuesday, 13.09.11, 8:00 p.m.
Ilmenau's Festival Hall

Programme

Philharmonic Orchestra Jena

* **Johannes Brahms (1833-1897)**
  Academic Festive Overture

* **Max Bruch (1838-1920)**
  Concert for Violin and Orchestra No 1 g-Moll op. 26

* **Johannes Brahms**
  Symphony No 2 D-Dur op. 73

Violin Donata Sailer

Conductor Marc Tardue

Admission 10 EUR

Scientific guided tours

Wednesday,14.09.11, 1:00 - 2:00 p.m. (each tour starts at the same time)

All lecturers and participants are kindly invited to take part in the guided tours of research centres of the Ilmenau University of Technology.

The following tours will be held:

Meeting place: Entrance to the Humboldt Building

* Competence Centre Virtual Reality
* Center for Micro- and Nanotechnologies (ZMN)
* Special research area 622 Nano-positioning and nano-measuring machines
* Automotive Engineering
* Laser Lab and Laboratory for Precision Machining
* Quality Assurance and Image Processing

Admission

Free of charge

Social Events

Excursion and Banquet

Wednesday, 14.09.11, 2:15 p.m.	Coaches depart from the Mensa (Refectory) for the excursion to Wartburg Castle (World Heritage) in Eisenach. English-speaking tourist guides will accompany you.
3:45 p.m. (approx.)	Arrival in Eisenach
4:10 - 5:10 p.m. **4:30 - 5:30 p.m.**	**Guided tour of the Wartburg Castle – 1st Group** **Guided tour of the Wartburg Castle – 2nd Group**
	You will visit the - Palas - Museum - Luther's room
6:00 p.m. (approx.)	Departure to Ilmenau
8:00 p.m.	Banquet in the Hotel „Tanne" Ilmenau Enjoy Thuringia's cuisine in an informal atmosphere with a musical programme by Acoustic Duo faBRi
Information:	www.hotel-tanne-thueringen.de
11:00 p.m. (approx.)	**End of the Banquet**
Admission	**59,50 EUR (**The Price includes 50,00 EUR net and 19% VAT (9,50 EUR))

Subject to alteration.

Further Events

Workshop 1st International Symposium OCTI 2011
Time: Tuesday, 13.09.2011
Location: Humboldt Building, Lecture Room 012

Focus:

The possible applications for OCT (optical coherence tomography) have grown tremendously in recent years because of such technical innovations as stable broadband light sources. In this context we at the Biomedical Engineering Department in Ilmenau University of Technology are investigating new applications of OCT for medical diagnostics. With the symposium it is our intention to do two things for biomedical engineers and for scientists in optics: to give them the chance of exchanging their latest insights and research questions on OCT and to enable them to establish contact with each other.

Topics:

Instrumentation & Algorithms

- Progress in light source technology
- Novel detectors and optical components
- Advanced image and segmentation algorithms
- New signal processing approaches

Ophthalmic OCT

- Retinal and anterior chamber imaging
- Functional OCT and contrast enhancement techniques
- Optical stimulation techniques

Biomedical Applications

- OCT applications in diagnostic analysis and therapy
- Clinical and preclinical studies
- Function OCT in Biomedicine
- Endoscopic, microscopic and vascular imaging

Multimodal OCT and Technical Applications

- Combinations with other imaging modalities and techniques (e.g. photoacoustic, fluorescence, ultrasound)
- Exogenous contrast enhancement techniques
- Further technical applications

Information: http://www.tu-ilmenau.de/octi2011/

Further Events

Workshop “Lebendige Glasoberflächen”
Zeit: Mittwoch, 14.09.2011
Ort: Arrheniusbau

Der dritte Workshop "Lebendige Glasoberflächen" findet im Rahmen des 56. Internationalen Wissenschaftlichen Kolloquiums an der TU Ilmenau am Mittwoch, dem 14.9.2011 statt. Er wird sich vor allem Aspekten der Reinigung und Oberflächenkonditionierung von Glas widmen. Weiterverarbeitung, Lagerung und Korrosion von Glas werden ebenfalls diskutiert.

Das Programm umfasst einen Überblicksvortrag zu Reinigungsmethoden und Oberflächenveränderungen während der Reinigung und Beiträge über neue Ergebnisse zur Oberflächenmodifikation. Es wird genügend Gelegenheit geboten, aktuelle Fragestellungen zu diskutieren und eigene Lösungsvorschläge vorzustellen. Der Workshop-Charakter wird unterstrichen durch die Begrenzung der Teilnehmerzahl auf 30.

Kontakt: Prof. Dr.-Ing. habil. Edda Rädlein
Fachgebiet Anorganisch-nichtmetallische Werkstoffe
Fachgebietsleiter
Tel: +49 3677 69-2802

Poster Session Workshop "Lebendige Glasoberflächen"
Zeit: Dienstag, 13.09.2011, 12:00 – 13:30 Uhr
Ort: Foyer Humboldtbau

U. Brokmann (D-Ilmenau), S. Schiermeyer (D-Wümbach)

UV transparent anti fouling coating of fused silica tube surfaces
UV-low pressure lamps are used for water purification. To protect these lamps and their power supplies from the surrounding media they are enclosed in fused silica tubes. In spite of the excellent stability of fused silica a loss of the uv output of the entire system cannot be avoided. Several organic and inorganic water components interact with the glass surface to build up persistent and uv-absorbing layers over the time of operation. This behaviour is described as "fouling" and is responsible for a significant decrease of the system life time. The aim of the project is the improvement of the performance of purification systems by applying functionalized coatings on the outside of the silica containment. Micro- and nanostructured oxides (SiO_2, Al_2O_3, TiO_2) processed by various coating methods (dip coating, spray coating, pyrolysis, plasma coating) were tested in different water qualities. Their influence on the deposition of contaminating layers on the effective areas of the UV-lamps is discussed in the present paper.

St. Harnisch, U. Brokmann (D-Ilmenau)

Topography and wetting behavior of micro structured photosensitive glass
Printing plates made from micro structured photosensitive glass can be used for printing of polymer electronics using the gravure printing process. Conventional metal gravure printing plates are mechanically engraved with an array of pyramid shaped cells. Inks for printed electronics are optimized with respect to their electrical properties. The printing of closed layers or fine lines is limited by their viscosity. A certain waviness of printed surfaces and line edges is characteristic for this process. Further miniaturization regarding layer thickness and width requires alternative structuring concepts and fluid management. Printing plates made from photosensitive glass provide an alternative. They posses a sufficient high mechanical stability and excellent chemical resistivity against usual organic solvents. One advantage of glass printed pattern is the high lateral resolution of > 15µm even with low viscosity inks in the range of 0,05 - 0,2 Pas. With photosensitive glass, three parameters can be varied to control the wetting behavior: surface chemistry, crystalline or glassy state and topography. With a student research project, topography design was investigated as a tool for fluid management. The surface states were varied from glass to glass ceramic and from polished smoothly to rough surfaces with stochastic or ordered pattern. First results on the influence of the topography on the wetting behavior of photosensitive glass will be presented.

Further Events

Workshop "Virtual Engineering throughout the Product Lifecycle"
Time: Thursday, 15.09.2011
Location: Ernst-Abbe Building and Fraunhofer IDMT Building

9:00 a.m. – 12:00 noon Lectures and Demonstrations
12:00 noon – 1:00 p.m. Lunch
1:00 p.m. – 3:00 p.m. Open Discussions

Further Events

1. Workshop Oberflächentechnik
Zeit: Freitag, 16.09.2011
Ort: Humboldtbau, Raum 129

Die Veranstaltung findet im Rahmen des „56. Internationalen Wissenschaftlichen Kolloquiums“ (IWK) der TU Ilmenau statt und setzt den traditionellen „Workshop Plasma- und Oberflächentechnik“ fort. Sie ist aber in diesem Jahr erstmals auf alle Gebiete der Oberflächentechnik erweitert worden und trägt damit dem aktuellen Trend und den Entwicklungen in unserem Institut Rechnung.

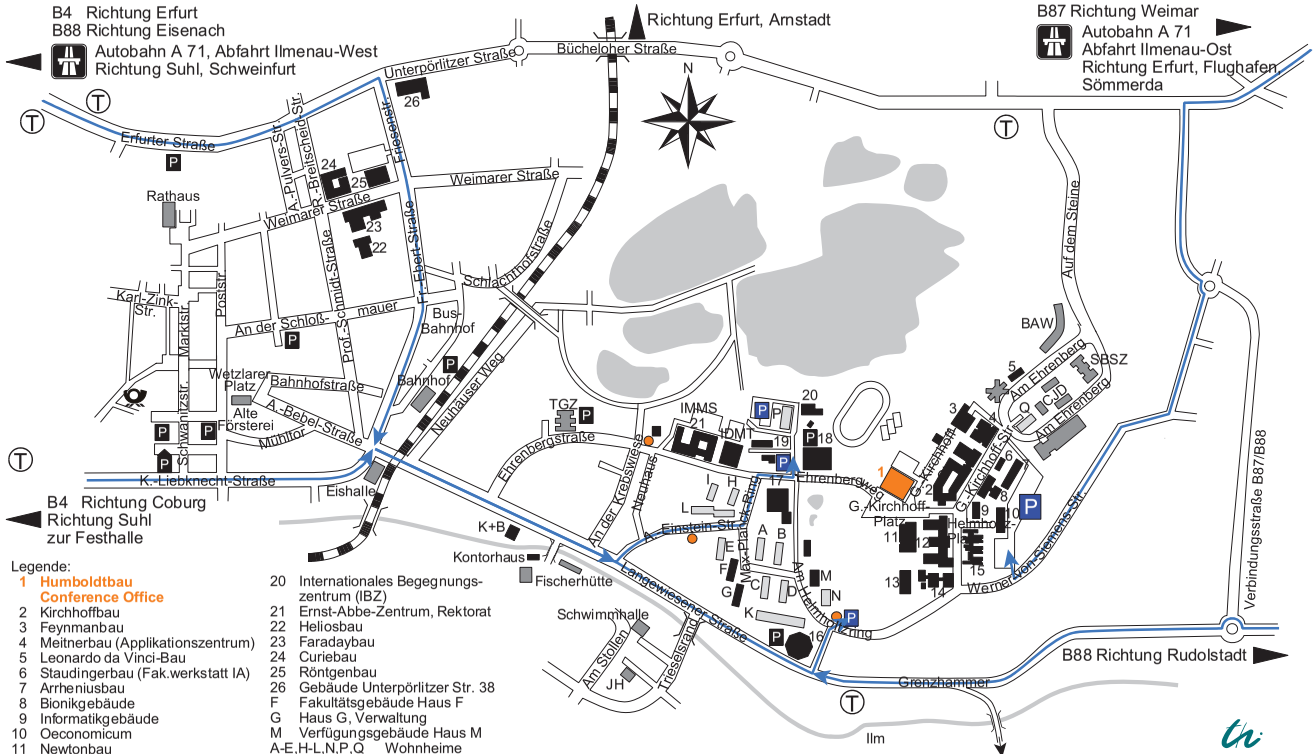
Der Workshop will Experten aus Industrie und Forschung die Möglichkeit zum Erfahrungsaustausch, zur Weiterbildung und zur Förderung fachlicher und persönlicher Kontakte geben. Traditionsgemäß wird der Diskussion viel Zeit gewidmet.

Es besteht natürlich die Gelegenheit zur Präsentation von Vorträgen, Postern oder anderen Ausstellungsmaterialien, insbesondere zu folgenden Schwerpunkten:

- Elektrochemische und galvanische Verfahren
- Thermisches Spritzen
- Dünnschicht-Plasmatechnik
- Innovative Konzepte und Werkstoffe für die Oberflächentechnik.

Kontakt: PD Dr.-Ing. habil. Birger Dzur
Fakultät für Elektrotechnik und Informationstechnik
Fachgebiet Plasma- und Oberflächentechnik
Fachgebietsleiter
Tel: +49 3677 69-2835

List of Authors



Legende:

1	**Humboldtbau Conference Office**	20	Internationales Begegnungszentrum (IBZ)
2	Kirchhoffbau	21	Ernst-Abbe-Zentrum, Rektorat
3	Feynmanbau	22	Heliosbau
4	Meitnerbau (Applikationszentrum)	23	Faradaybau
5	Leonardo da Vinci-Bau	24	Curiebau
6	Staudingerbau (Fak.werkstatt IA)	25	Röntgenbau
7	Arrheniusbau	26	Gebäude Unterpörlitzer Str. 38
8	Bionikgebäude	F	Fakultätsgebäude Haus F
9	Informatikgebäude	G	Haus G, Verwaltung
10	Oeconomicum	M	Verfügungsgebäude Haus M
11	Newtonbau	A-E,H-L,N,P,Q	Wohnheime
12	Helmholtzbau	IDMT	Fraunhofer-Institut für Digitale Medientechnologie
13	Projekthalle	IMMS	Institut für Mikroelektronik- und Mechatroniksysteme
14	Rechenzentrum u. Medienstudio	K+B	Gebäude Langewiesener Str. 22
15	Zusebau	TGZ	Technologie-und Gründerzentrum
16	Leibnizbau, Universitätsbibliothek	BAW	Bundesanstalt für Wasserbau
17	Mensa, Akademisches Service Center (ASC)	SBSZ	Staatliches Berufsschulzentrum
18	Campus-Sporthalle, Sportplatz	CJD	Christliches Jugenddorf
19	Hörsaal 2	JH	Jugendherberge
		●	Orientierungstafeln

ILMENAU UNIVERSITY OF TECHNOLOGY

Orientation Plan

Stand Juni 2011

The Organising committee of the 56th International Scientific Colloquium (56. IWK) would like to thank the sponsors and companies for the financial contribution of:

sartorius mechatronics	Sartorius Weighing Technology GmbH, Göttingen
TETRA	TETRA, Gesellschaft für Sensorik, Robotik und Automation mbh, Ilmenau
VDI	Thüringer Bezirksverein e.V. des VDI
stw Steinbeis-Transferzentrum Qualitätssicherung & Bildverarbeitung	Steinbeis-Transferzentrum Qualitätssicherung & Bildverarbeitung, Ilmenau
JOHANNES HÜBNER GIESSEN renewable energy	J O H A N N E S H U E B N E R Fabrik elektrischer Maschinen GmbH, Giessen
IBS Precision Engineering	IBS Precision Engineering Deutschland GmbH, Stuttgart
ANDRÄ GmbH	Andrä GmbH Aluminiumbau & Grafittechnik, Ilmenau
OWIS®	OWIS GmbH, Staufen
SIOS Meßtechnik GmbH	SIOS Meßtechnik GmbH, Ilmenau
IMMS	IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH, Ilmenau
XPRESS Precision Engineering	Xpress Precision Engineering B.V., Eindhoven, Niederlande
PI	Physik Instrumente (PI) GmbH & Co.KG, Karlsruhe
Springer the language of science	Springer-Verlag GmbH, Berlin
SIEMENS	Siemens AG, Rudolstadt